REPORT #
RRTAC 86-5

Chemical and Mineralogical Properties of Overburden: Plains Hydrology and Reclamation Project

Heritage Fund

Alberta

LAND CONSERVATION AND
RECLAMATION COUNCIL
Reclamation Research
Technical Advisory Committee

REPORT #RRTAC 86-5

CHEMICAL AND MINERALOGICAL PROPERTIES OF OVERBURDEN: PLAINS HYDROLOGY & RECLAMATION PROJECT

by

Anna Maslowski Schutze

Alberta Research Council

for

Reclamation Research Technical Advisory Committee

of the

Alberta Land Conservation and Reclamation Council

1986

STATEMENT OF OBJECTIVE

The recommendations and conclusions in this report are those of the authors and not those of the Alberta Government or its representatives.

This report is intended to provide Government and Industry staff with up to date technical information to assist in the development of guidelines and operating procedures. The report is also available to the Public so that interested individuals similarly have access to the best available information on land reclamation topics.

ALBERTA'S RECLAMATION RESEARCH PROGRAM

The regulation of surface disturbances in Alberta is the responsibility of the Land Conservation and Reclamation Council. The Council executive consists of a chairman from the Department of the Environment and two deputy chairman from the Department of Forestry, Lands & Wildlife. Among other functions, the Council oversees programs for reclamation of abandoned disturbances and reclamation research. The reclamation research program was established to provide answers to the many practical questions which arise in reclamation. Funds for implementing both the operational and research programs are drawn from Alberta's Heritage Savings Trust Fund.

To assist in technical matters related to the development and administration of the research program the Council appointed the Reclamation Research Technical Advisory Committee (RRTAC). The Committee first met in March, 1978 and consists of eight members representing the Alberta Departments of Agriculture, Energy, Forestry, Lands & Wildlife, Environment and the Alberta Research Council. The Committee meets regularly to update research priorities, review solicited and unsolicited research proposals, arrange workshops and otherwise act as a referral and coordinating body for Reclamation Research.

Additional information on the Reclamation Research Program may be obtained by contacting:

Dr. P.F. Ziemkiewicz, Chairman
Reclamation Research Technical Advisory Committee
Alberta Energy
2nd Floor, 10909 Jasper Avenue
EDMONTON, Alberta
T5J 3M8 (427-8042)

This Report may be cited as:

Maslowski-Schutze, A.
1986 Chemical and Mineralogical Properties of Overburden: Plains Hydrology and Reclamation Project. Alberta Land Conservation and Reclamation Council Report #RRTAC 86-5 - 50p.

Additional copies may be obtained from:

Publication Services
Queen's Printer
11510 Kingsway Avenue
EDMONTON, Alberta
T5G 2Y5

TABLE OF CONTENTS

		Page
LIST OF FIGURES		iii
PREFACE		viii
ABSTRACT		xi
ACKNOWLEDGEMENTS		xiii
1.	INTRODUCTION	1
2.	PHYSICAL AND CHEMICAL PROPERTIES OF THE STRATIGRAPHIC UNITS	4
	Texture	4
2.2	Clay Mineralogy	8
2.3	Carbonate Content	8
2.4	Saturation-Paste Extract	13
2.4.1	Saturation Percentage	13
2.4.2	pH of Saturated-Paste Extract	22
2.4.3	Electrical Conductivity of Saturated-Paste Extract	22
2.4.4	Soluble Sodium	24
2.4.5	Soluble Calcium	28
2.4.6	Soluble Magnesium	28
2.4.7	Soluble Potassium	32
2.4.8	Sodium Adsorption Ratio	32
2.4.9	Soluble Sulfate	32
2.4.10	Soluble Bicarbonate	40
2.4.11	Soluble Chloride	40
2.5	Exchangeable Cations	40
2.5.1	Exchangeable Sodium	40
2.5.2	Exchangeable Calcium	42
2.5.3	Exchangeable Magnesium	46
2.5.4	Exchangeable Potassium	46
2.5.5	Cation Exchange Capacity	46
3.	REFERENCES CITED	49
4.	APPENDIX	50
4.1	Chemical and Physical Analysis of Overburden Samples from the Battle River Study Area	50

LIST OF FIGURES

		Page
1.	Map of the Battle River Study Area Showing Location of PHRP Coreholes from which Samples Were Obtained	2
2.	Geophysical Log of Corehole BR-26 in the Battle River Study Area Showing Lithostratigraphic Subdivisions of the Overburden	3
3.	Mean Grain Size Distribution of 190 Samples from the 11 Stratigraphic Units Delineated and Characterized in the Battle River Study Area.....	5
4.	Cumulative Frequency Distribution of Grain Size of Sand, Silt, and Clay, from 36 Glacial Drift Samples in the Battle River Study Area.....	6
5.	Cumulative Frequency Distribution of Grain Size Data from 147 Bedrock Samples in the Battle River Study Area: (a) sand-size grains, (b) silt and clay-size grains.....	7
6.	Percentage of Clay Mineral Phases Identified from the 11 Lithostratigraphic Units Delineated in the Battle River Study Area.....	9
7.	Cumulative Frequency Distribution of Percentage of Smectite Clay from 34 Glacial Drift Samples and 147 Bedrock Samples in the Battle River Study Area.....	10
8.	Weight Percent Calcite and Dolomite Determined from the 11 Lithostratigraphic Units Delineated in the Battle River Study Area.....	11
9.	Cumulative Frequency Distribution of Weight Percent of Calcite, Dolomite and Total Carbonate from 36 Drift Samples and 141 Bedrock Samples in the Battle River Study Area	12
10.	Histogram of Total Carbonate (Base 10 Logarithm) from 35 Drift Samples in the Battle River Study Area	14
11.	Plots by Depth of Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR), Saturation Percentage (Satn %), pH, and Sulfate Concentration from Saturation-Paste Extracts from Coreholes BR-5 and BR-24 in the Battle River Study Area	15

LIST OF FIGURES (CONTINUED)

		Page
12.	Plots by Depth of Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR), Saturation Percentage (Satn %), pH, and Sulfate Concentration from Saturation-Paste Extracts from Coreholes BR-6 and BR-23 in the Battle River Study Area	16
13.	Plots by Depth of Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR), Saturation Percentage (Satn %), pH, and Sulfate Concentration from Saturation-Paste Extracts from Coreholes BR-9 and BR-10 in the Battle River Study Area	17
14.	Plots by Depth of Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR), Saturation Percentage (Satn %), pH, and Sulfate Concentration from Saturation-Paste Extracts from Corehole BR-25 in the Battle River Study Area	18
15.	Plots by Depth of Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR), Saturation Percentage (Satn %), pH, and Sulfate Concentration from Saturation-Paste Extracts from Corehole BR-26 in the Battle River Study Area	19
16.	Plots by Depth of Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR), Saturation Percentage (Satn %), pH, and Sulfate Concentration from Saturation-Paste Extracts from Corehole BR-29 in the Battle River Study Area	20
17.	Cumulative Frequency Distribution of Saturation Percentage from 35 Drift Samples and 128 Bedrock Samples in the Battle River Study Area	21
18.	Histogram of Saturation Percentage Data (Base 10 Logarithm) from 128 Bedrock Samples in the Battle River Study Area	21
19.	Cumulative Frequency Distribution of pH in Saturation-Paste Extracts from 35 Drift Samples and 128 Bedrock Samples in the Battle River Study Area	23
20.	Cumulative Frequency Distribution of Electrical Conductivity (EC) from Saturation-Paste Extracts of 35 Drift and 128 Bedrock Samples in the Battle River Study Area	25

LIST OF FIGURES (CONTINUED)

		Page
21.	Histogram of Electrical Conductivity Data (Base 10 Logarithm) from Saturation-Paste Extracts of 35 Drift Samples and 128 Bedrock Samples in the Battle River Study Area	26
22.	Cumulative Frequency Distribution of Soluble Sodium from Saturation-Paste Extracts of 35 Drift Samples and 128 Bedrock Samples in the Battle River Study Area	27
23.	Histogram of Soluble Sodium (Base 10 Logarithm) from Saturation-Paste Extracts of 128 Bedrock Samples in the Battle River Study Area	27
24.	Cumulative Frequency Distribution of Soluble Calcium from Saturation-Paste Extracts of 35 Drift Samples and 128 Bedrock Samples in the Battle River Study Area	29
25.	Histogram of Soluble Calcium (Base 10 Logarithm) from Saturation-Paste Extracts of 35 Drift Samples and 128 Bedrock Samples in the Battle River Study Area	30
26.	Cumulative Frequency Distribution of Soluble Magnesium from Saturation-Paste Extracts of 35 Drift Samples and 128 Bedrock Samples in the Battle River Study Area	31
27.	Cumulative Frequency Distribution of Sodium Adsorption Ratios (SAR) Calculated from Saturation-Paste Extracts of 35 Drift Samples and 128 Bedrock Samples in the Battle River Study Area.....	33
28.	Histogram of Sodium Adsorption Ratios (SAR) Calculated from Saturation-Paste Extracts of 128 Bedrock Samples in the Battle River Study Area.....	33
29.	Cumulative Frequency Distribution of Soluble Sulfate from Saturation-Paste Extracts of 35 Drift Samples and 128 Bedrock Samples in the Battle River Study Area	34
30.	Histogram of Soluble Sulfate (Base 10 Logarithm) from Saturation-Paste Extracts of 128 Bedrock Samples in the Battle River Study Area	34

LIST OF FIGURES (CONTINUED)

		Page
31.	Scatter Diagrams Showing Relationship Between Soluble Sulfate and Soluble Sodium from Saturation-Paste Extracts of 35 Drift Samples and 128 Bedrock Samples in the Battle River Study Area	36
32.	Scatter Diagrams Showing Relationship Between Electrical Conductivity and Soluble Sodium from Saturation-Paste Extracts of 35 Drift Samples and 128 Bedrock Samples in the Battle River Study Area	37
33.	Scatter Diagrams Showing Relationship Between Electrical Conductivity and Soluble Sulfate from Saturation-Paste Extracts of 35 Drift Samples and 128 Bedrock Samples in the Battle River Study Area	38
34.	Scatter Diagrams Showing Relationship Between pH and Soluble Sulfate in Samples from Each of the 11 Stratigraphic Units Delineated in the Battle River Study Area	39
35.	Cumulative Frequency Distribution of Exchangeable Sodium Determined from 35 Drift Samples and 147 Bedrock Samples in the Battle River Study Area	41
36.	Histogram of Exchangeable Sodium (Base 10 Logarithm) Determined from 35 Drift Samples and 147 Bedrock Samples in the Battle River Study Area	43
37.	Scatter Diagram Showing Relationship Between Clay and Exchangeable Sodium from 147 Bedrock Samples in the Battle River Study Area	44
38.	Cumulative Frequency Distribution of Exchangeable Calcium Determined from 35 Drift and 147 Bedrock Samples in the Battle River Study Area.....	45
39.	Histogram of Exchangeable Calcium (Base 10 Logarithm) Determined from 147 Bedrock Samples in the Battle River Study Area	45

LIST OF FIGURES (CONCLUDED)

		Page
40.	Cumulative Frequency Distribution of Exchangeable Magnesium Determined from 35 Drift Samples and 147 Bedrock Samples in the Battle River Study Area	47
41.	Cumulative Frequency Distribution of Cation Exchange Capacity (CEC) Determined from 35 Drift Samples in the Battle River Study Area.....	48
42.	Histogram of Cation Exchange Capacity (CEC) Determined from 35 Drift Samples in the Battle River Study Area.....	48

PREFACE

This is one of a series of reports that presents the findings of the Plains Hydrology and Reclamation Project (PHRP), an interdisciplinary study that focuses primarily on hydrologic aspects of reclamation of surface coal mines in the plains of Alberta. This research has been conducted by the Alberta Research Council as part of the Alberta Government's Reclamation Research Program. The program is managed by the Land Conservation and Reclamation Council and is supported by the Heritage Trust Fund.

The focus of PHRP is to develop a predictive framework that will permit projection of success for reclamation and impact of mining on water resources on a long-term basis. The predictive framework is based on an understanding of processes acting within the landscape so that in the future, mine sites that are not totally analogous to those that have been studied can be evaluated as well.

The project involves a holistic approach to reclamation by integration of studies of geology, hydrogeology, and soils, not only in the proposed mining area, but also in the adjoining unmined areas. This approach permits the assessment of impacts and long-term performance, not only in reclaimed areas, but also in the surrounding area.

The research of PHRP has been directed toward the following two major objectives and eight subobjectives.

Objective A

To evaluate the potential for reclamation of lands to be surface mined. The focus is on features of the landscape that make it productive in a broad sense not restricted to revegetation. This objective was organized into five subobjectives.

1. To assess and evaluate the potential for long-term degradation of reclaimed soils through salt build-up.
2. To assess and evaluate the effectiveness of topographic modification and selective placement of materials to mitigate deleterious impacts on chemical quality of groundwater.

3. To assess the availability of water supply in, or beneath, cast overburden to support post-mining land use, including both quantity and quality considerations.
4. To evaluate the productivity potential (capability) of post-mining landscapes and the significance of changes in capability as a result of mining.
5. To assess and evaluate limitations to post-mining land use posed by physical instability of cast overburden.

Objective B

To evaluate the long-term impact of mining and reclamation on water quantity and quality. This objective was organized into three subobjectives.

1. To assess and evaluate the long-term alteration of quality of groundwater in cast overburden and surface water fed from mine spoil as a result of the generation of weathering products.
2. To assess and evaluate infiltration, groundwater recharge, and groundwater-surface water interactions within cast overburden.
3. To characterize the groundwater chemistry generated within cast overburden.

Studies directed at these objectives began in 1979 at the Battle River site in east-central Alberta. Work began in 1982 at a second study area at Highvale Mine south of Lake Wabamun. Significant progress has been on all project objectives by the end of the first phase of study in March 1984. This present series of reports summarizes the state of our knowledge at the end of this first phase of study. Work is now continuing on the Phase II objectives to gain an even greater understanding of the complex physical and chemical processes in reclaimed landscapes.

This report is one of a series that describes the Battle River study site. As such, it does not relate directly to any specific objectives, but rather supports, in an indirect way, all the subobjectives.

This report describes a wide range of chemical, physical and mineralogical properties of the overburden materials at the Battle River Site. In an effort to identify individual beds within the bedrock overburden that might be significantly different in terms of reclamation potential, a wide variety of properties of the overburden were determined in addition to those normally evaluated in assessing suitability of overburden materials. The only consistently recognized difference among materials was that the bedrock material is significantly different from the overlying glacial drift in nearly every property. No consistent differences were recognized within the bedrock and, as a result, all the bedrock overburden has been treated as a single unit for most properties.

ABSTRACT

Overburden core samples were collected from 10 sites in the Battle River study area; 36 drift samples and 147 bedrock overburden samples were analyzed for a variety of chemical and mineralogical properties. Electrical conductivity (EC), sodium adsorption ratio (SAR), pH, saturation percentage, and soluble sulfate content, the most important of these properties from the standpoint of reclamation, are summarized here. Numerous other parameters are discussed in the paper itself.

Much of the drift is of acceptable quality to provide subsoil material for reclamation. However, about 25 percent of the drift samples are limited by salinity having EC values in excess of 4.0 dS/m; about 35 percent of the drift samples are limited by sodicity, having SAR values greater than 10. All of the bedrock samples are unacceptable as subsoil material as a result of sodicity limitation; 100 percent of the SAR values exceed 14.6. Only 2 percent of the bedrock samples have the additional limitation of EC values in excess of 4.0 dS/m.

The electrical conductivity (EC) of drift samples ranges from 0.13 to 7.67 dS/m, with a median of about 1.75 dS/m. About 75 percent of the drift samples have EC values less than 4.0 dS/m. The EC of bedrock samples varied from 0.38 to 5.50 dS/m, with a median of 1.0 dS/m. Less than 2 percent of the bedrock samples have EC values greater than 4.0 dS/m.

At five sites (coreholes 9, 23, 24, 25 and 49), the highest values of EC occurred at the top of the glacial drift. The EC progressively decreases with depth in the drift. A shift toward lower values of EC occurs at the bedrock contact. A different pattern occurred at three sites (5, 6 and 26), where EC values increased downward from the surface to maximum values in the interval from 3 to 8 m. Beneath this depth, the EC values decreased, reaching the range of 0.5 to 2.75 dS/m in the bedrock.

Sodium adsorption ratio (SAR) of drift samples ranges from 0.30 to 34.50, with a median of 5.0. About 60 percent of the drift samples have SAR values less than 7.5, with about 65 percent less than 10. SAR values of bedrock samples ranged from 14.65 to 108.0.

The mean SAR value of the normally distributed data from bedrock samples is 46.7.

Acidic to neutral pH values (4.8 to 7.1) characterize 30 percent of the drift samples. These values occur in the upper few metres of sites in the western part of the study area (sites 5, 6, 9, 10), which is lower in elevation than the eastern part of the area, and in a depressional area in the eastern part of the study area (site 49). Below this interval and at the remainder of the sites, pH values in drift samples are neutral to basic, with maximum values of 9.6. At six sites on the upland in the eastern part of the area (sites 23, 24, 25, 26, 27 and 29), no acidic pH values were encountered. Only about 7 percent of the bedrock samples had pH values less than 7.0. These lower pH values correspond to some samples from coal-bearing horizons.

Saturation percentage for drift is significantly lower than for bedrock. Values of saturation percentage in drift samples range from 33 to 127 percent, with a median value of 53 percent. Values of saturation percentage in bedrock range from 51 to 489 percent, with a median of about 184 percent.

In general, the sulfate content of both drift and bedrock samples is low, with median values of 7.5 meq/L and 5.2 meq/L, respectively. However, the drift contains significantly more high values of sulfate than does the bedrock. Values ranging from 20 meq/L to 53.6 meq/L characterize 10 percent of the bedrock samples. In contrast, 28 percent of the drift samples contain more than 20 meq/L sulfate, with a maximum value twice as great as for bedrock at 106 meq/L. High values of soluble sulfate correspond to low values of pH and carbonate in some samples from coal-bearing horizons. This suggests that acid production from oxidation of sulfide or organic compounds in close proximity to coal beds can overwhelm the buffering capacity of the overburden in isolated locations. No evidence is available to suggest that low pH water will pose even a minor problem because of the very large buffering capacity of the overburden, which is related to both the abundance of carbonate minerals and the abundance of unstable, base-saturated smectitic clay minerals.

ACKNOWLEDGEMENTS

This study was supported by funds from the Alberta Heritage Savings Trust Fund, administered through the Land Conservation and Reclamation Council. The support and assistance of Alberta Power Ltd., Luscar Ltd. and Manalta Coal Ltd. and landowners in the Battle River project area, is acknowledged.

1. INTRODUCTION

Continuous cores from surface through the Battle River Bed were collected at 10 sites within the Battle River study area (Figure 1). These cores were sampled at about 0.5 m intervals, and at more closely spaced intervals where distinct lithologic changes were observed. The samples were analyzed for grain size, clay mineralogy, carbonate mineralogy, cation exchange characteristics and soluble salt content using the saturation-paste extract technique.

The overburden at Battle River was divided into 11 stratigraphic units on the basis of lithology and stratigraphic continuity (Figure 2). The 11 units delineated are:

1. Glacial Drift
2. Paintearth Interval
3. Paintearth Bed
4. Marker Interval
5. Marker Interval, Basal Shale
6. Battle River, Cycle IV
7. Battle River, Cycle III
8. Battle River, Cycle II
9. Battle River, Cycle I
10. Battle River Bed
11. Delta Sandstone

All data were entered onto computer files and coded for well depth and stratigraphic unit. The data were then tested statistically using the computer statistical package "Midas" (Statistical Research Laboratory, University of Michigan 1976). The initial statistical examination of the data yielded very few meaningful results. It was recognized that much of the geochemical and physical data did not conform to normal distributions and as a result simple parametric statistical inferences about the data could not be made. In order to use the inference procedures that are dependent on the normality assumption, those variables that showed a log-normal distribution of the original data were recalculated using this transformation. These logarithmic values generally improved the distribution of the data with respect to normality and more accurate means and standard deviations could be reported for these variables. Variables that did not possess normal or log-normal distributions were described only by their median values and cumulative frequency distributions.

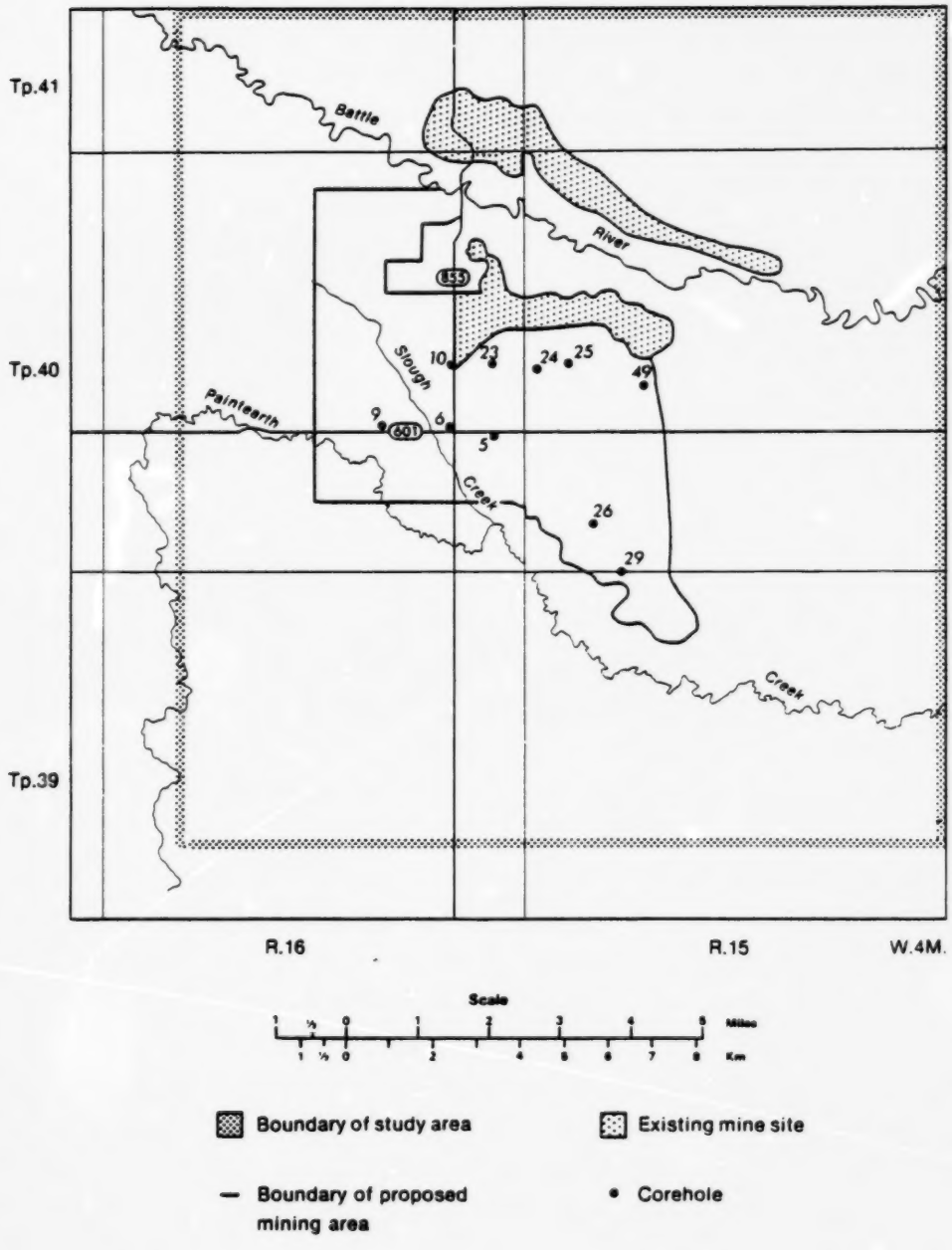

Figure 1. Map of the Battle River study area showing location of PHRP coreholes from which samples were obtained.

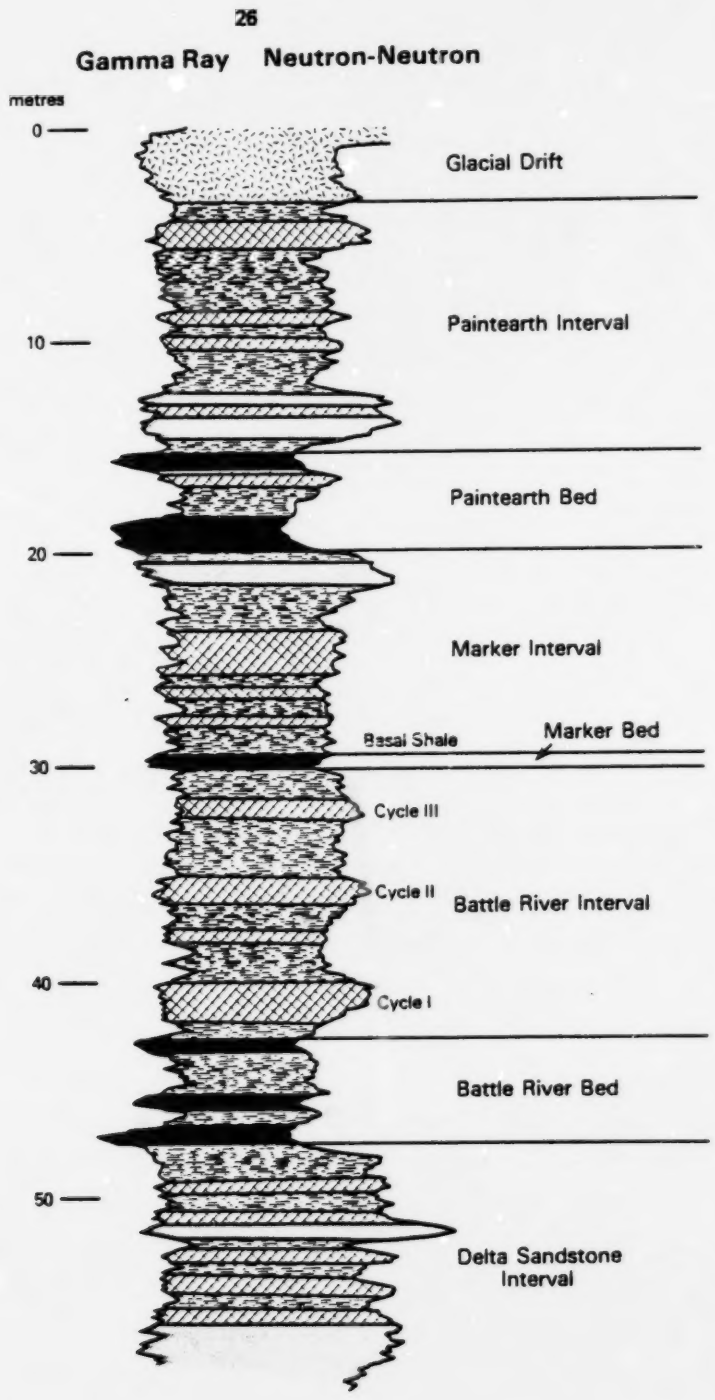

Figure 2. Geophysical log of Corehole BR-26 in the Battle River study area showing lithostratigraphic subdivisions of the overburden.

2. PHYSICAL AND CHEMICAL PROPERTIES OF THE STRATIGRAPHIC UNITS

2.1 TEXTURE

The particle size distribution within samples was determined by sieve analysis and the hydrometer method (McKeague 1978).

The overburden at Battle River is dominated by fine grained clastic sediment. The glacial drift has a slightly larger sand component than do the bedrock units. The bedrock units, on the other hand, have a slightly larger clay component (Figure 3).

Five of the stratigraphic units are dominated by clay sized (<4μm) particles, five units are dominated by silt-sized (0.004 to 0.05 mm) particles, and one unit, the glacial drift, is dominated by sand size (0.05 to 2 mm) particles (Figure 3). Very fine to fine sand (0.05 to 0.25 mm) is the second most abundant size fraction in seven of the stratigraphic units; in the other four units medium silt (0.005-0.02 mm) is the second most abundant fraction. The average percentage of clay (<4μm) within the eleven units ranges from 22.5 to 46.2 percent.

Thirty-six samples from the glacial drift yield a mean particle size distribution of 37 percent sand (>0.05 mm), 35 percent silt (0.05 to 0.004 mm) and 28 percent clay (<0.004 mm) (Figure 3). Ninety percent of the glacial drift samples contain less than 46 percent sand (>0.05 mm) (Figure 4). Sixty percent of the drift samples contain more than 27 percent clay (<0.004 mm) (Figure 4).

Of the 147 samples from the ten bedrock stratigraphic units, the mean particle size distribution is 28 percent sand (>0.05 mm), 36 percent silt (0.05 to 0.004 mm) and 36 percent clay (<0.004 mm). Seventy percent of the bedrock samples contain less than 34 percent sand (2 to 0.05 mm) (Figure 5a), and 90 percent of the bedrock samples contain more than 18 percent clay (<0.004 mm) (Figure 5b). Nearly all the sand that occurs within the samples is between 0.05 and 0.25 mm in size (Figure 5a). The partings in the Paintearth, Marker and Battle River Beds average more than 44 percent clay (Figure 3).

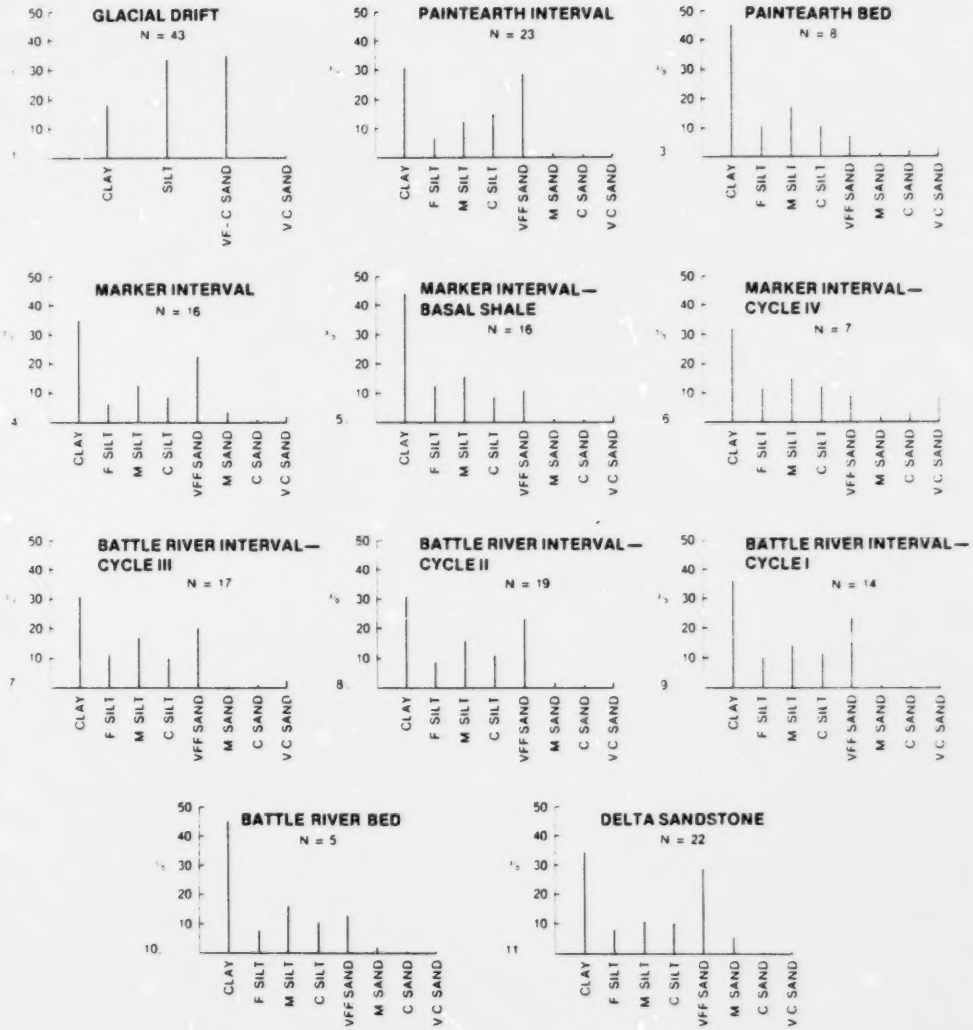

Figure 3. Mean grain size distribution of 190 samples from the 11 stratigraphic units delineated and characterized in the Battle River study area.

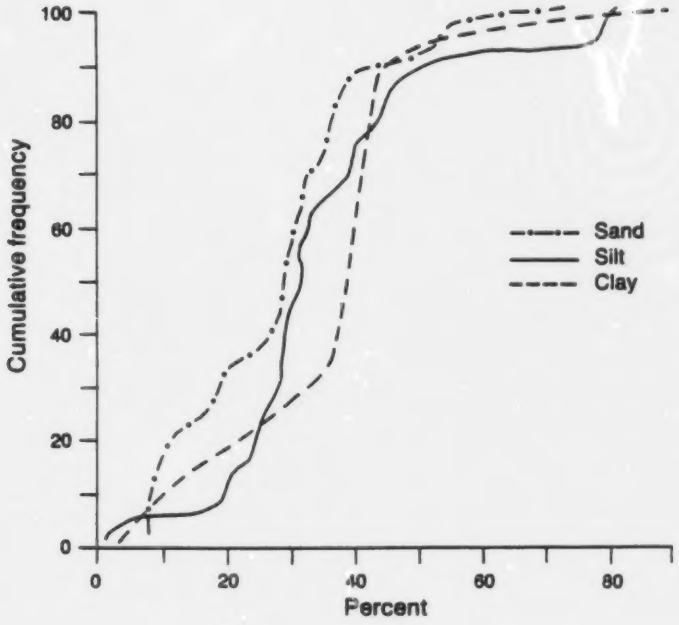

Figure 4. Cumulative frequency distribution of grain size of sand, silt, and clay, from 36 glacial drift samples in the Battle River study area.

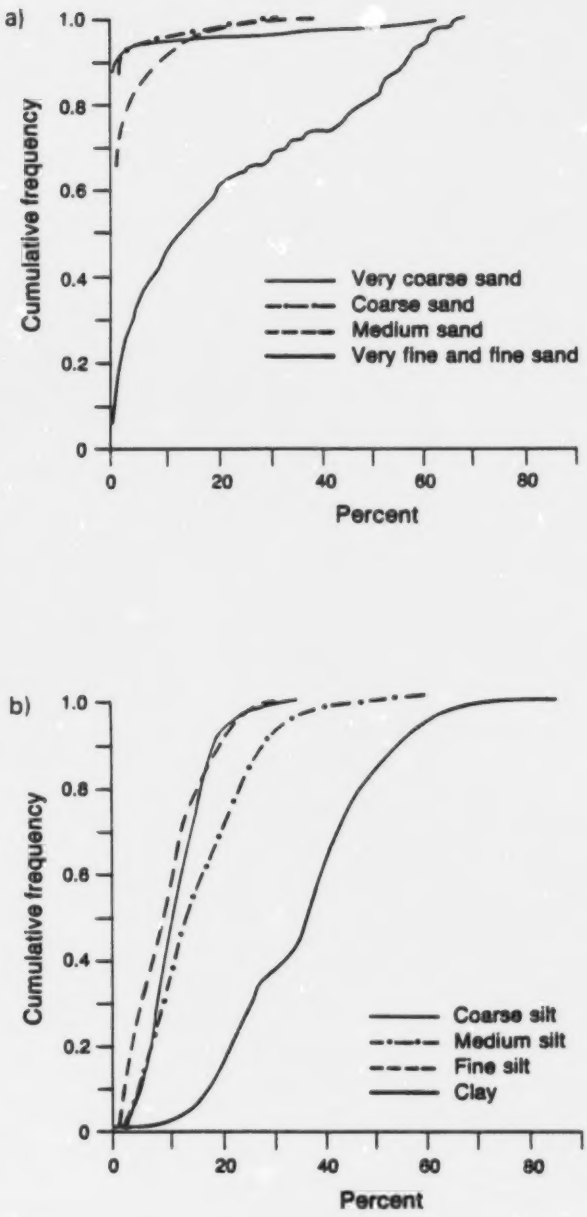

Figure 5. Cumulative frequency distribution of grain size data from 147 bedrock samples in the Battle River study area: (a) sand-size grains, (b) silt and clay-size grains.

2.2 CLAY MINERALOGY

The clay mineralogy of the <2μm fraction of 35 glacial drift samples and 147 bedrock samples was determined by x-ray diffraction methods.

Smectite is the most abundant clay mineral phase in all eleven stratigraphic units. Illite, kaolinite and chlorite are, in decreasing amounts, the other phases present (Figure 6).

Seventy percent of the glacial drift samples contain more than 45 percent smectite (Figure 7). More than 30 percent illite also occurs in 70 percent of the samples. The median value of kaolinite within the drift samples is 10 percent. Ninety percent of the drift samples contain less than 10 percent chlorite.

Seventy percent of the bedrock samples contain more than 70 percent smectite (Figure 7). Only 10 percent of the bedrock samples contain more than 30 percent illite. The median value of kaolinite within bedrock samples is 3 percent and only 10 percent of the 147 samples contain more than 10 percent kaolinite. Ninety percent of the bedrock samples contain less than 10 percent chlorite.

2.3 CARBONATE CONTENT

The weight percent equivalent of carbonate in the samples was determined by the gravimetric method, in which CO_2 evolved by reaction with HCl in a closed system was translated back into equivalent $CaCO_3$ or $CaMg(CO_3)_2$. It is possible that other soluble carbonates, such as siderite ($FeCO_3$) or sodium carbonate, were also being measured in this procedure. Some samples yielded very high carbonate percentages and it is probable that concretionary bands and nodules contributed to these high percentages.

The weight equivalent of calcite and dolomite within the glacial drift, as determined from 36 samples, ranges between 0 and 14.7 percent and 0 and 6 percent respectively (Figure 8). The median amount of calcite and dolomite within the drift is 1.9 and 2.2 percent by weight respectively (Figure 9a, b). The total amount of carbonate within the drift varies between 0 and 20.1 percent by weight (Figure 7c). The original total carbonate data for drift samples do not plot as a normal distribution. Therefore, these data were transformed to base 10 logarithms in order to bring the

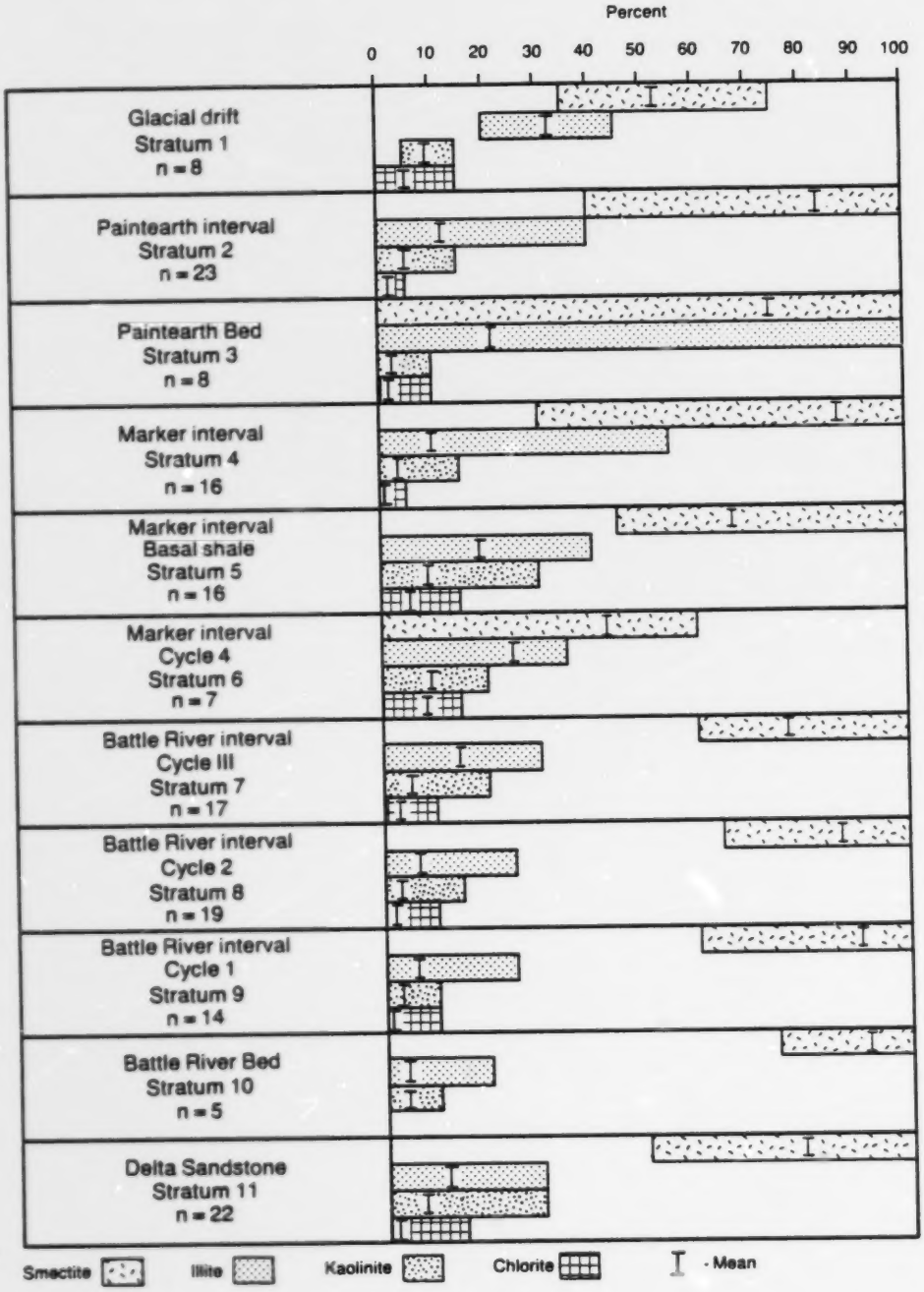

Figure 6. Percentage of clay mineral phases identified from the 11 lithostratigraphic units delineated in the Battle River study area.

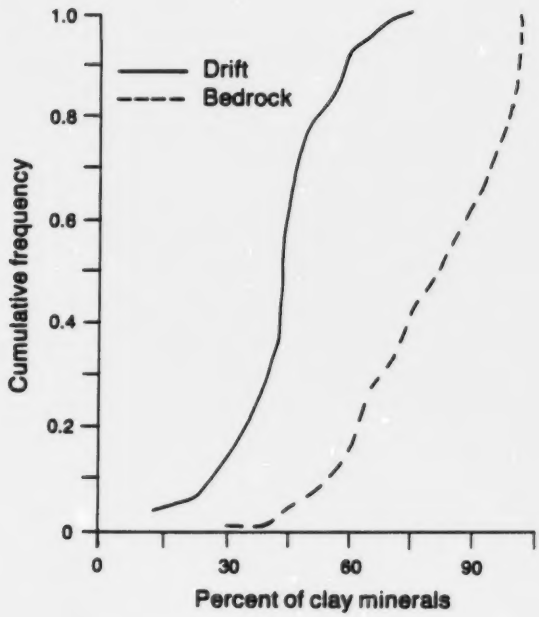

Figure 7. Cumulative frequency distribution of percentage of smectite clay from 34 glacial drift samples and 147 bedrock samples in the Battle River study area.

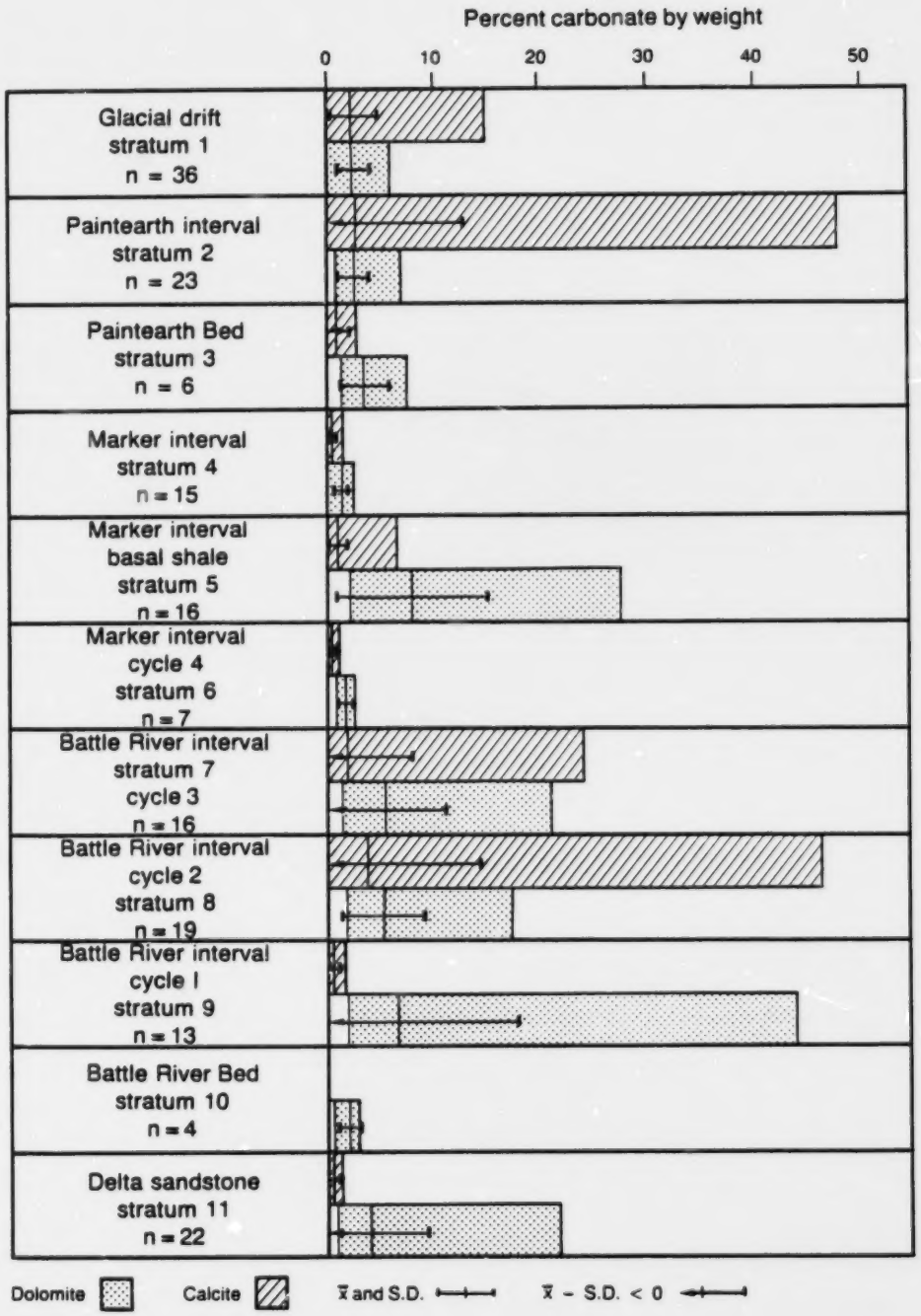

Figure 8. Weight percent calcite and dolomite determined from the 11 lithostratigraphic units delineated in the Battle River study area.

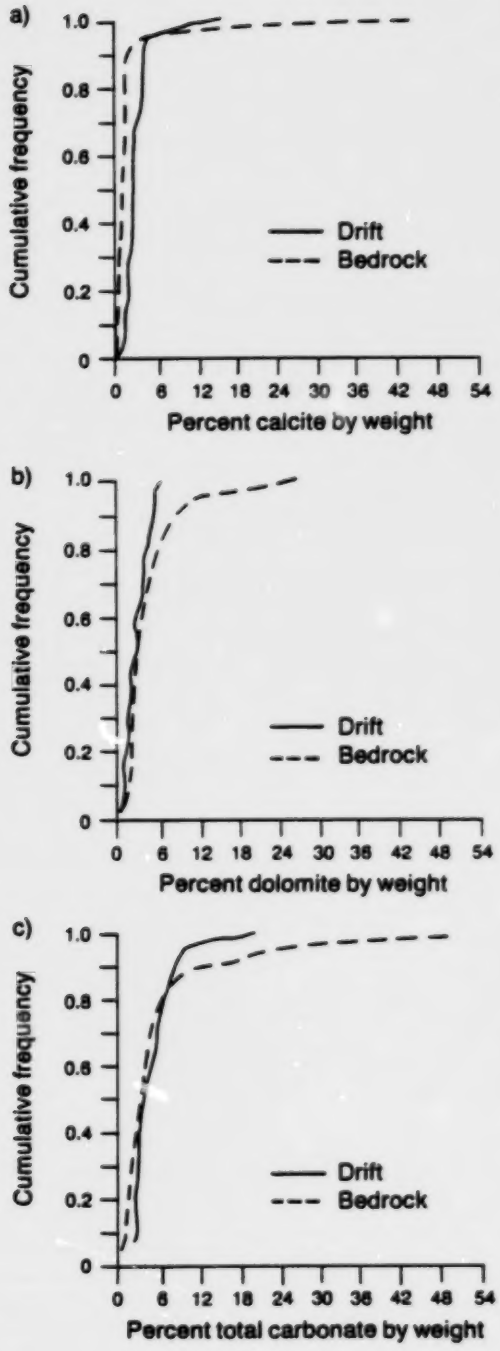

Figure 9. Cumulative frequency distribution of weight percent of calcite, dolomite and total carbonate from 36 drift samples and 141 bedrock samples in the Battle River study area.

distribution closer to normal. The mean total carbonate within drift samples calculated from transformed data is 4.5 percent by weight (Figure 10a).

Within bedrock samples, the concentration of calcite ranges from 0 to 46.7 percent by weight and dolomite ranges from 0 to 44.2 percent by weight. The range for total carbonate is 0.20 to 52.0 percent by weight. The median values calculated from the original data for calcite, dolomite, and total carbonate are 0.2, 2.6 and 3.1 percent by weight, (Figure 9). The original data for carbonate minerals plot as positively skewed distributions; therefore, these data were transformed to base 10 logarithms. The resulting histograms for calcite and dolomite are again positively skewed, but to a lesser degree; the histogram of total carbonate is approximately log-normal. The mean values of calcite, dolomite and total carbonate, as determined from transformed data, are 0.7, 3.0 and 3.3 percent by weight, respectively.

Stratum 5, the basal shale of the Marker Interval, and stratum 8, Cycle II of the Battle River Interval, have the highest median values for total carbonate, 6.20 and 4.60 percent by weight respectively (Figure 8).

2.4 SATURATION-PASTE EXTRACT

Saturation-paste extracts were prepared from 43 samples of glacial drift material and 128 samples of bedrock material to determine the saturation percent and soluble salt content of the overburden. The data for electrical conductivity (EC), SAR, saturation percentage, pH, and sulfate content are summarized for each of the coreholes in Figures 11 to 16.

2.4.1 Saturation Percentage

The saturation percentage of glacial drift samples varies between 33 and 127 percent. The median value is 53 percent (Figure 17).

The saturation percentage of bedrock samples varies between 51 and 489 percent. The median value calculated from the original data is 184 percent (Figure 17). The original data yield a positively skewed distribution. These data, transformed to base 10 logarithms, yield a mean of 179 percent (Figure 18).

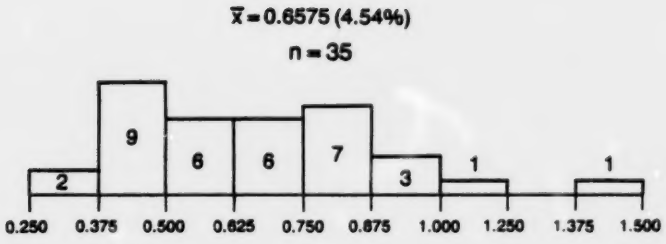

Figure 10. Histogram of total carbonate (base 10 logarithm) from 35 drift samples in the Battle River study area.

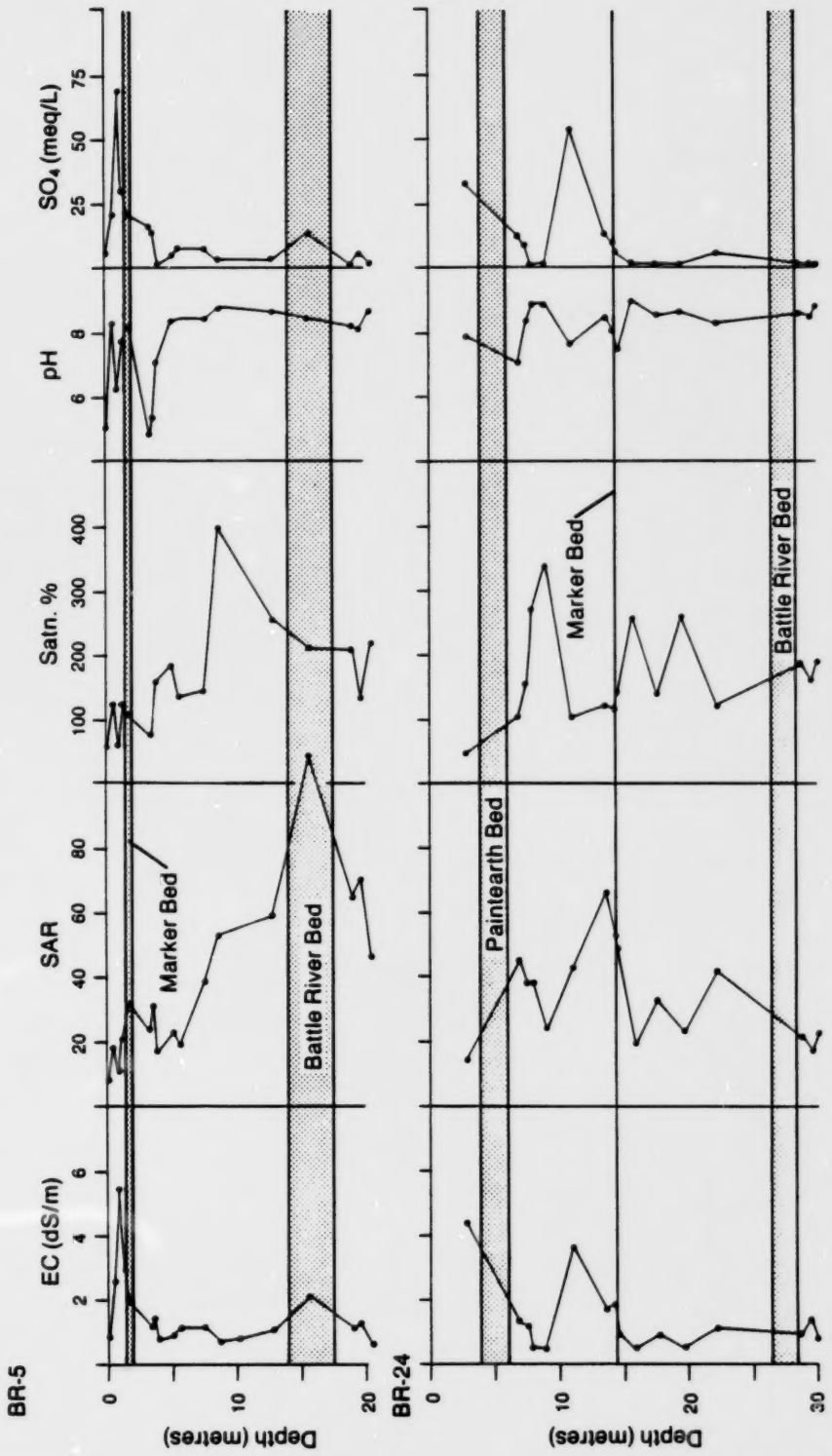

Figure 11. Plots by depth of electrical conductivity (EC), sodium adsorption ratio (SAR), saturation percentage (Satn %), pH, and sulfate concentration from saturation-paste extracts from Coreholes BR-5 and BR-24 in the Battle River study area.

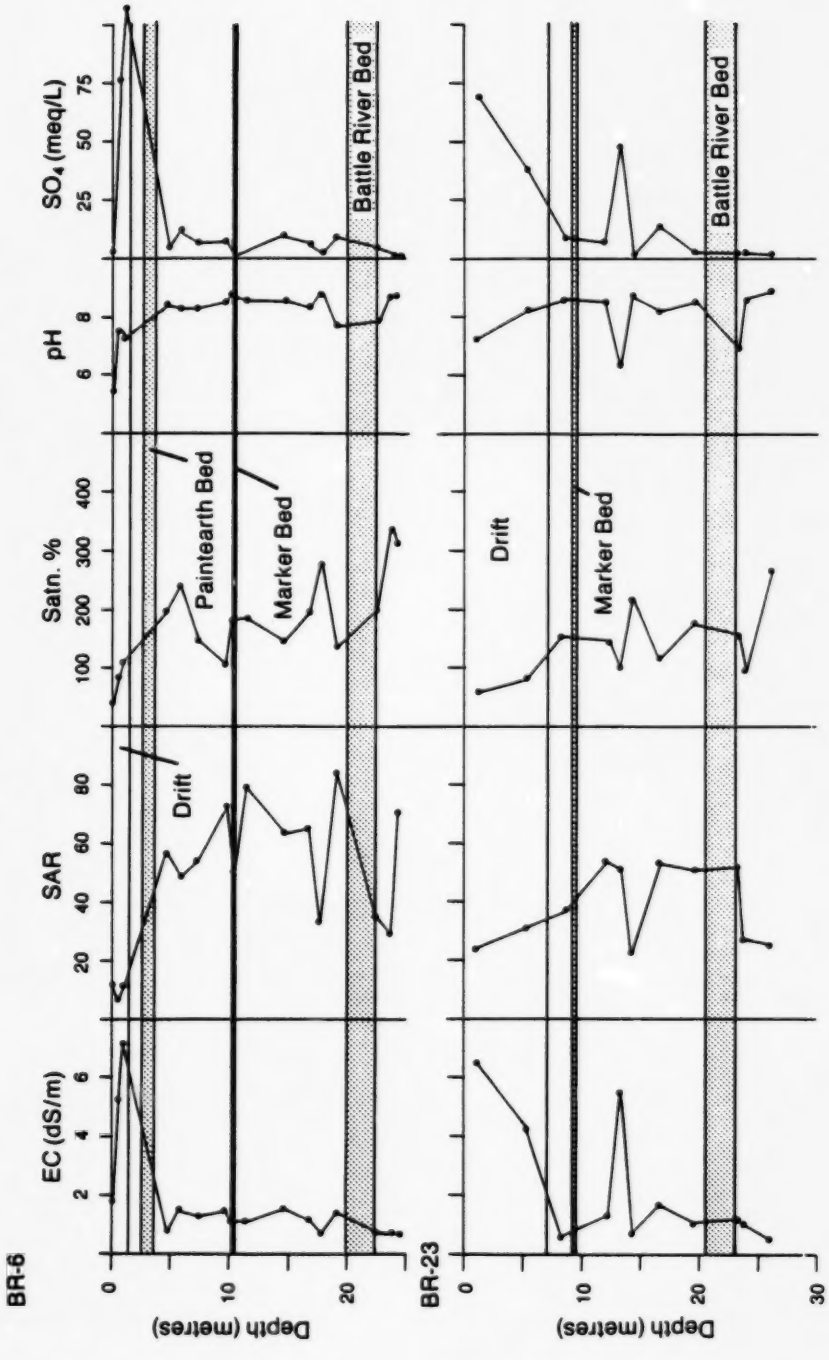

Figure 12. Plots by depth of electrical conductivity (EC), sodium adsorption ratio (SAR), saturation percentage (Satn %), pH, and sulfate concentration from saturation-paste extracts from Coreholes BR-6 and BR-23 in the Battle River study area.

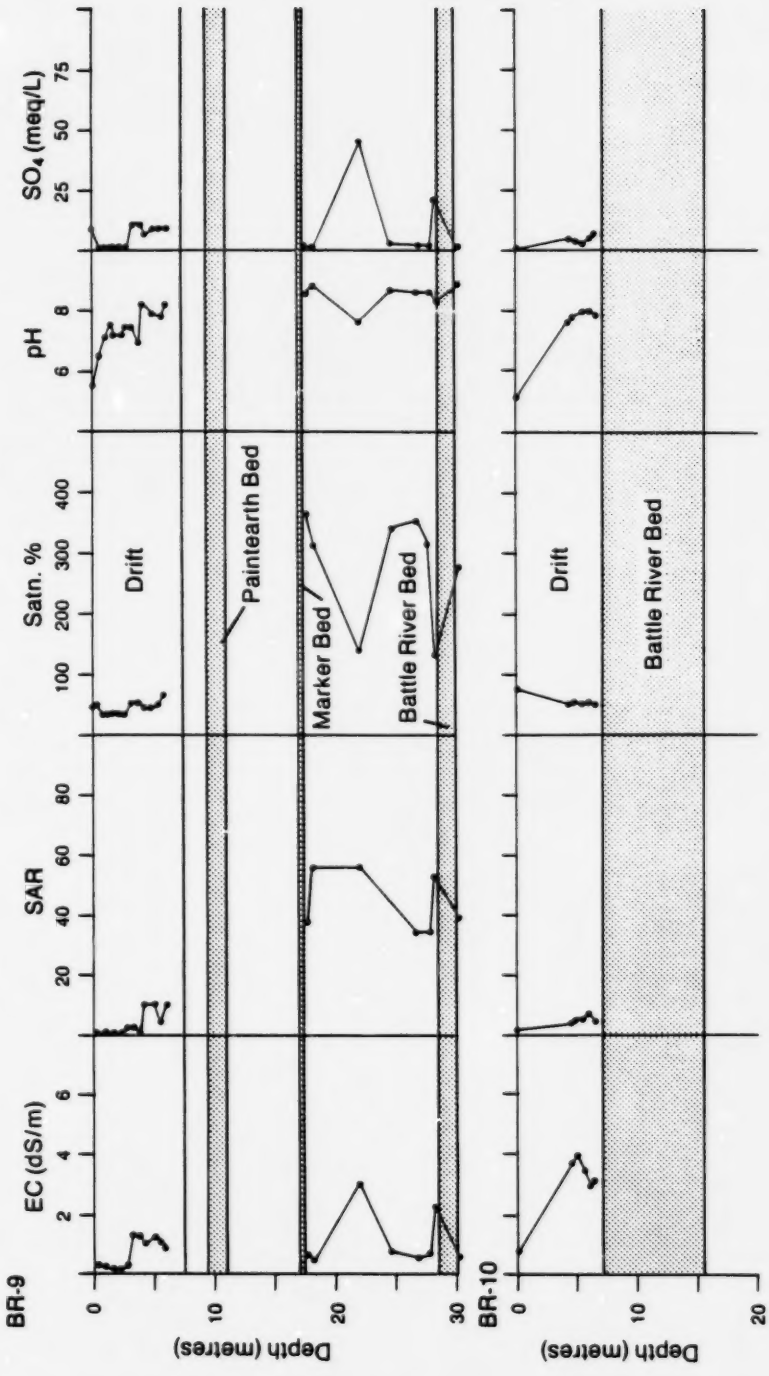

Figure 13. Plots by depth of electrical conductivity (EC), sodium adsorption ratio (SAR), saturation percentage (Satn %), ph, and sulfate concentration from saturation-paste extracts from Coreholes BR-9 and BR-10 in the Battle River study area.

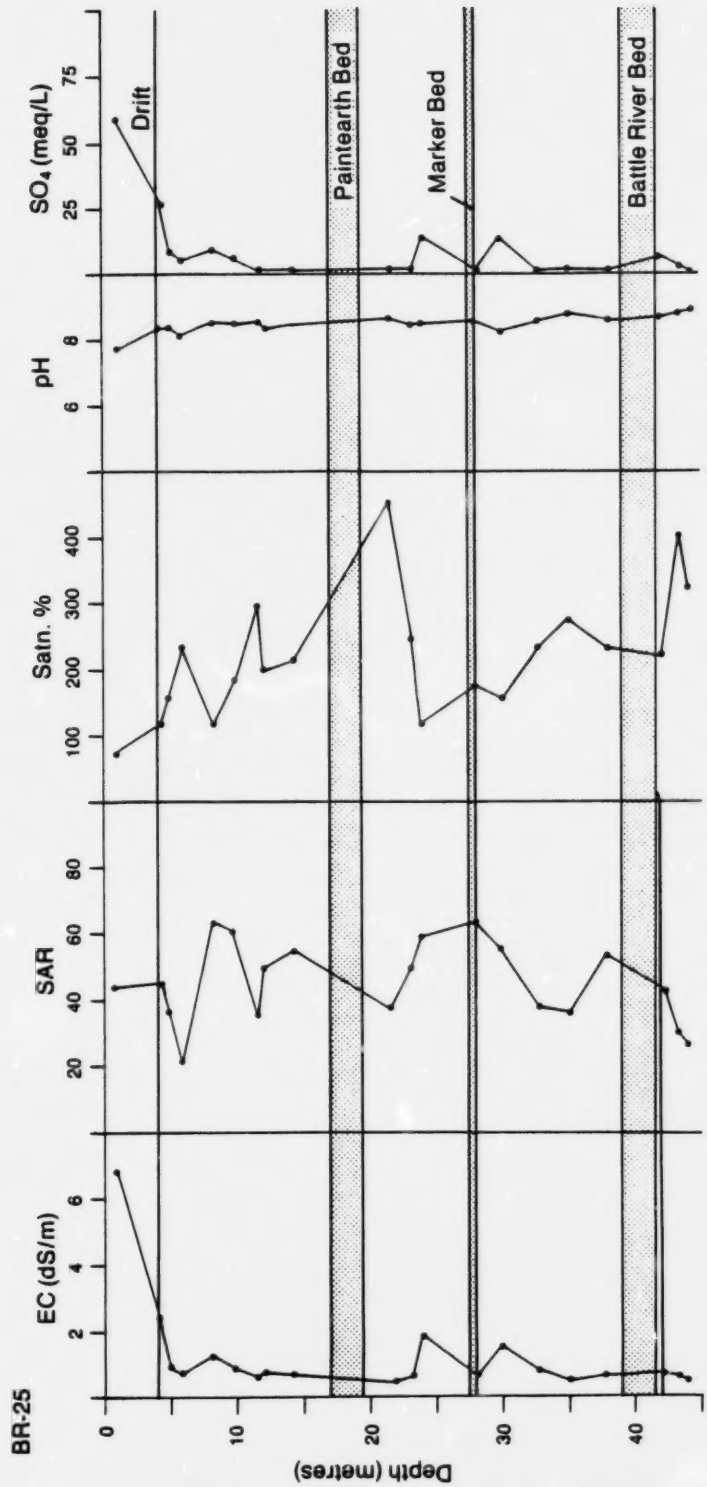

Figure 14. Plots by depth of electrical conductivity (EC), sodium adsorption ratio (SAR), saturation percentage (Satn %), pH, and sulfate concentration from saturation-paste extracts from Corehole BR-25 in the Battle River study area.

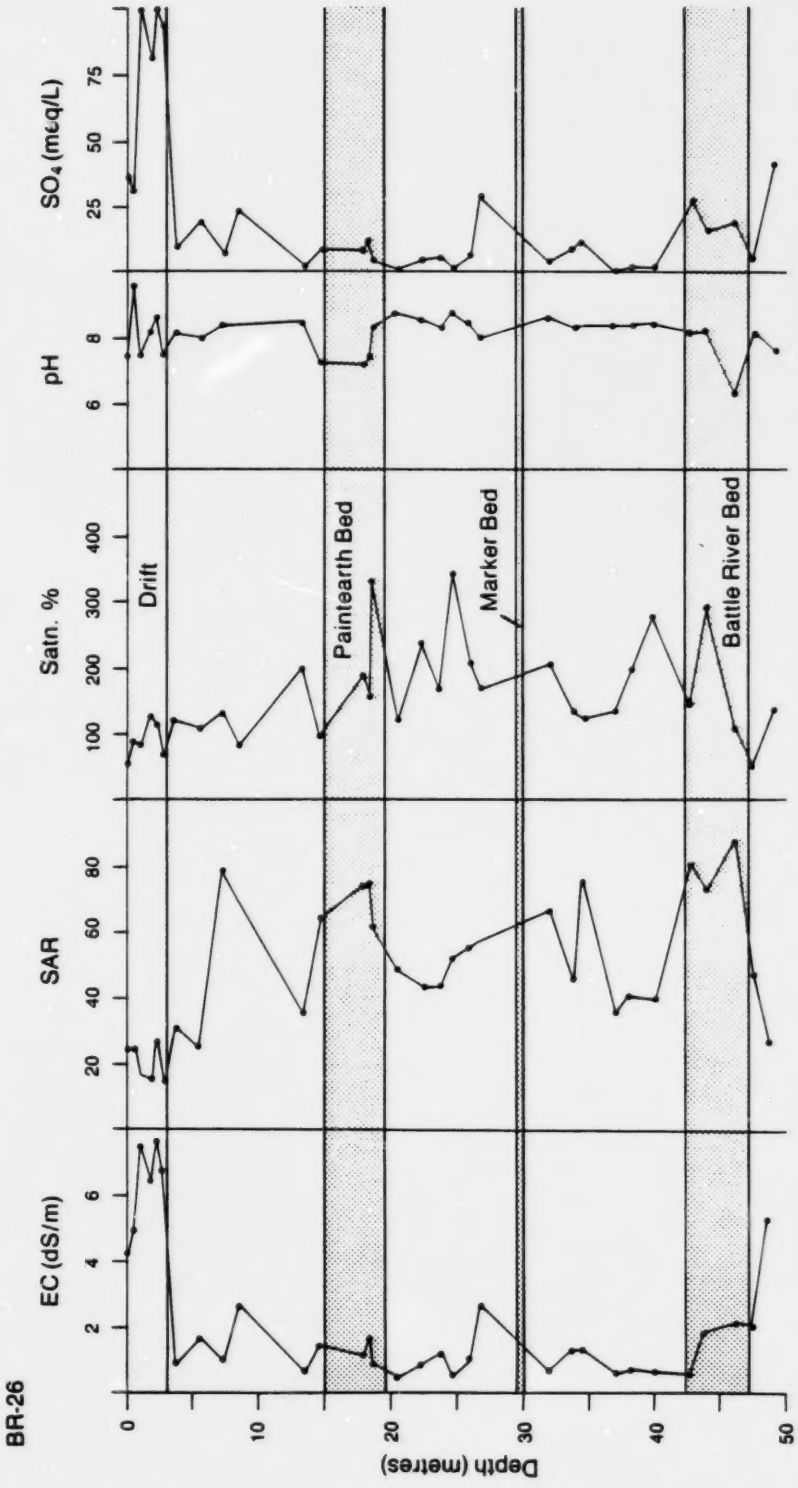

Figure 15. Plots by depth of electrical conductivity (EC), sodium adsorption ratio (SAR), saturation percentage (Satn %), pH, and sulfate concentration from saturation-paste extracts from Corehole BR-26 in the Battle River study area.

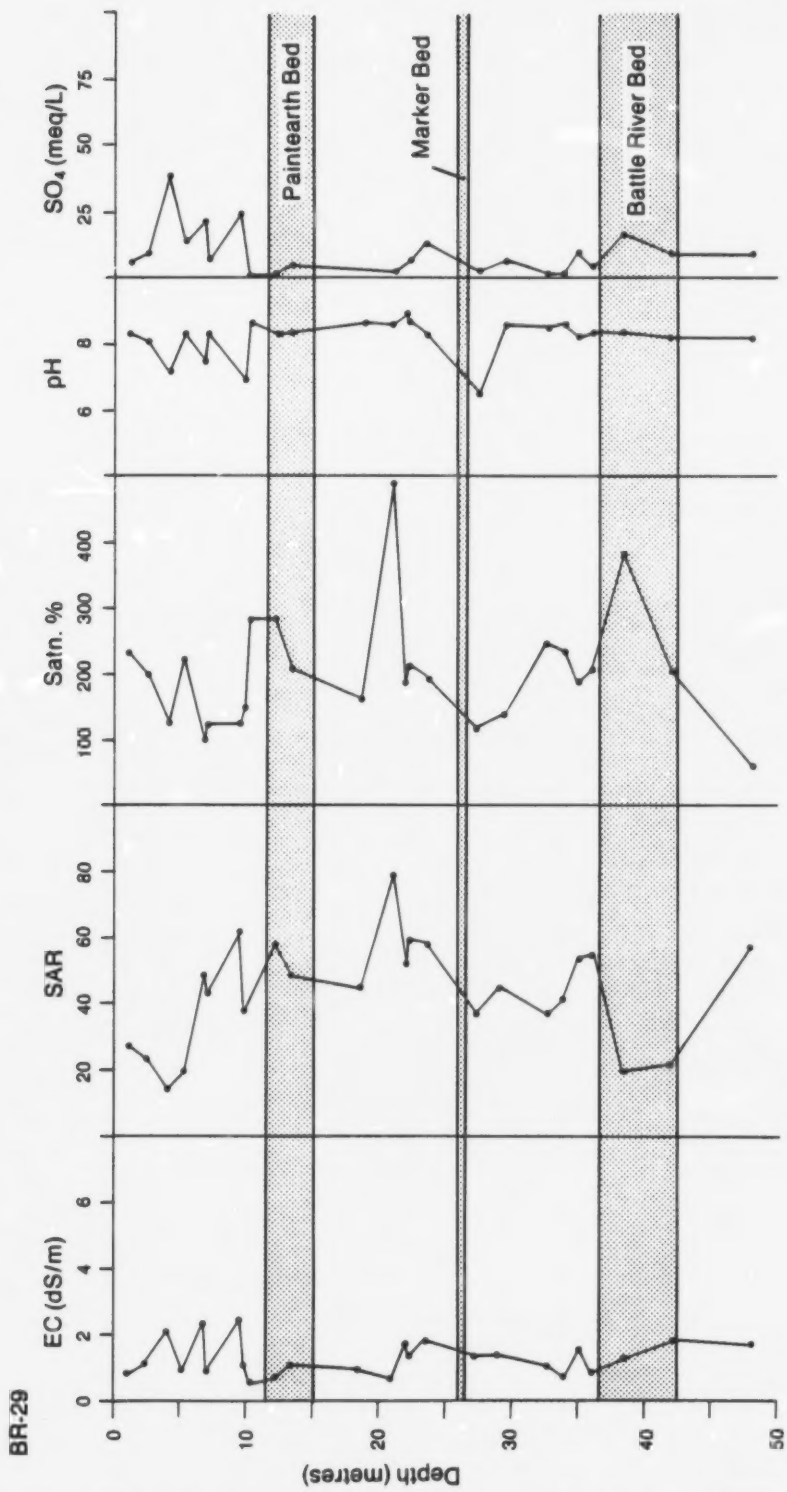

Figure 16. Plots by depth of electrical conductivity (EC), sodium adsorption ratio (SAR), saturation percentage (Satn %), pH, and sulfate concentration from saturation-paste extracts from Corehole BR-29 in the Battle River study area.

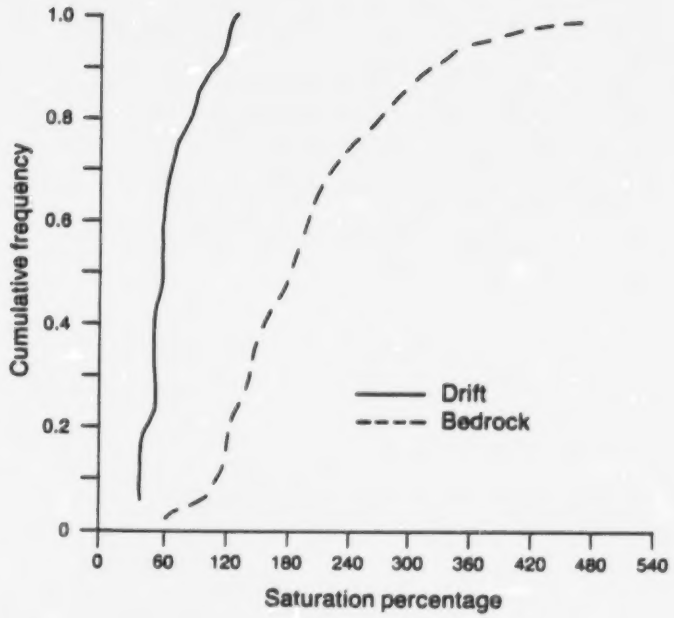

Figure 17. Cumulative frequency distribution of saturation percentage from 35 drift samples and 128 bedrock samples in the Battle River study area.

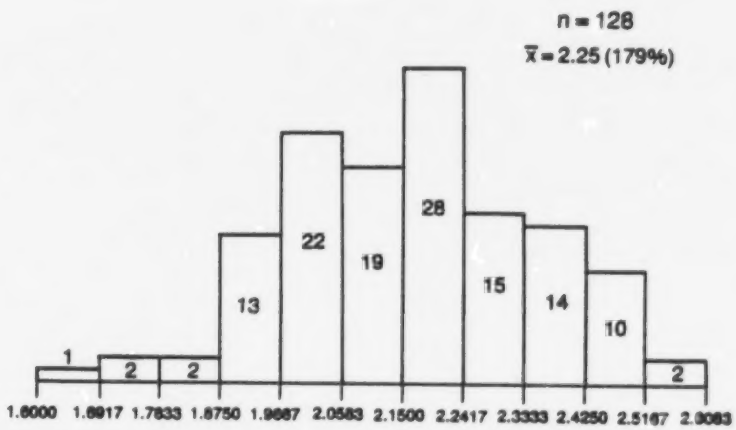

Figure 18. Histogram of saturation percentage data (base 10 logarithm) from 128 bedrock samples in the Battle River study area.

Saturation percentage is generally controlled, to some degree, by the amount of smectitic clays present within the sample. Surprisingly very few significant correlations were obtained between saturation percentage and smectite content for the 128 bedrock samples. Stratigraphic units 5 and 7 yielded correlation coefficients of 0.6837 and 0.7570 for these two variables; all other strata yielded very low correlation coefficients.

2.4.2 pH of Saturated-Paste Extract

The pH of drift samples ranges from 5.0 to 9.6 and averages 7.3. Thirty percent of the drift samples have a pH of less than 7.1 (Figure 19). The pH of bedrock samples ranges from 4.8 to 9.0 and averages 8.2. Less than ten percent of the bedrock samples have a pH of less than 7.0 (Figure 19).

The mean pH of the 11 stratigraphic units ranges from 7.3 to 8.5; therefore, the overburden can be generally classified as neutral to moderately alkaline. Lower pH values (i.e., near 7.0) were generally measured in samples from stratigraphic units that are in contact with coal beds, for example, BR-24 (Figure 11), BR-23 (Figure 12), BR-26 (Figure 15), and BR-29 (Figure 16).

Acidic to neutral pH values (4.8 to 7.1) characterize 30 percent of the drift samples. These values occur in the upper few metres of sites in the western part of the study area which is lower in elevation than the eastern part of the area, at sites 5, 6, 9, 10 (Figures 11, 12, and 13), and in a depressional area in the eastern part of the study area (site 49). Below this interval and at the remainder of the sites, pH values in drift samples are neutral to basic, with maximum values of 9.6. At six sites (23, 24, 25, 26, 27 and 29) on the upland in the eastern part of the area (Figures 11, 12, 14, 15 and 16), no acidic pH values were encountered in the drift.

2.4.3 Electrical Conductivity of Saturated Paste Extract

The original data for electrical conductivity show positively skewed distributions when plotted in the form of histograms; therefore, these data were transformed into base 10 logarithms in order to allow parametric statistical descriptions of the data.

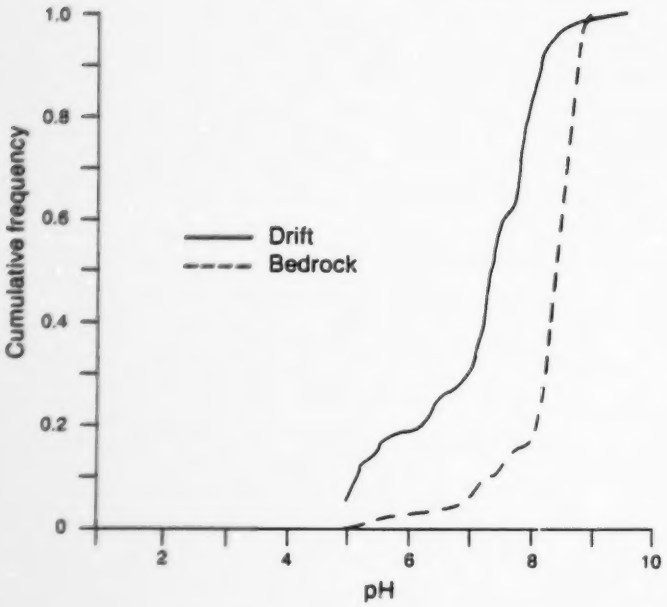

Figure 19. Cumulative frequency distribution of pH in saturation-paste extracts from 35 drift samples and 128 bedrock samples in the Battle River study area.

The electrical conductivity of 35 glacial drift samples varies between 0.13 and 7.67 dS/m. Seventy percent of the drift samples possess conductivities of less than 4 dS/m (Figure 20). The transformed data show a bimodal distribution; a small peak at the low end of the scale has a mean of 0.29 dS/m and a larger peak at the higher end of the scale has a mean of 3.09 dS/m (Figure 21a).

The electrical conductivity of 128 bedrock samples varies between 0.38 and 5.50 dS/m. Less than 2 percent of the bedrock samples yielded conductivities greater than 4 dS/m (Figure 20). The mean EC of the bedrock samples, as determined from transformed data, is 1.07 dS/m (Figure 21b).

2.4.4 Soluble Sodium

The concentration of soluble sodium within the glacial drift samples varies between 0.30 and 83.5 meq/L. Seventy percent of the drift samples contain less than 31 meq/L soluble sodium (Figure 22). The original data plot as a positively skewed histogram. The data, transformed to base 10 logarithms, yield a bimodal distribution with mean peaks at 0.93 and 24.55 meq/L.

The concentration of soluble sodium within bedrock samples varies between 3.00 and 91.74 meq/L, but 90 percent of the samples yield less than 33.78 meq/L soluble sodium (Figure 22). Eighty percent of the samples yield less than 25.3 meq/L. Again, the original data plot as a positively skewed histogram. The data transformed to base 10 logarithms yield a normal distribution with a mean of 14.26 meq/L soluble sodium (Figure 23).

The mean concentration of soluble sodium for each of the ten bedrock stratigraphic units, as determined from transformed data, varies between 10.0 and 34.1 meq/L. The highest mean concentrations are noted within the coal-bearing Battle River Bed (34.1 meq/L) and Marker Interval, Basal Shale (23.8 meq/L). The median values of soluble sodium for the bedrock units vary between 8.57 and 30.61 meq/L. The Battle River Bed and the Basal Shale of the Marker Interval have the highest median values of 30.61 meq/L and 23.65 meq/L, respectively.

A large part of the data regarding the abundance of sodium within the sediments points to a distinct association with

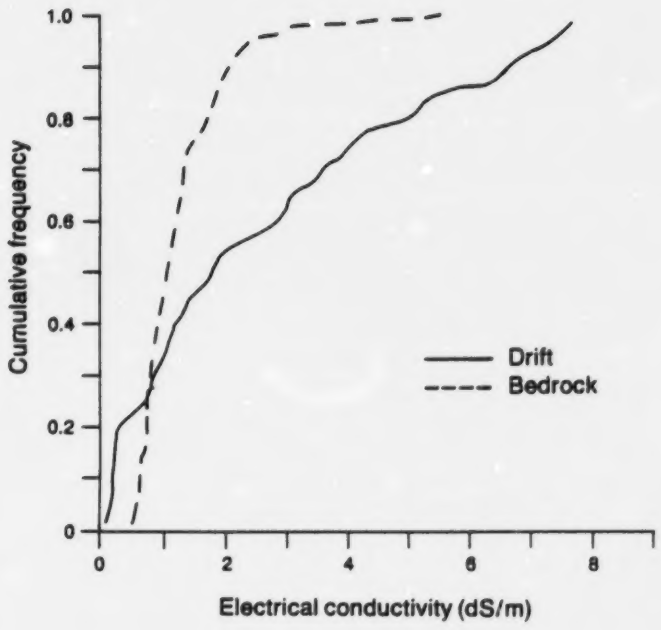

Figure 20. Cumulative frequency distribution of electrical conductivity (EC) from saturation-paste extracts of 35 drift and 128 bedrock samples in the Battle River study area.

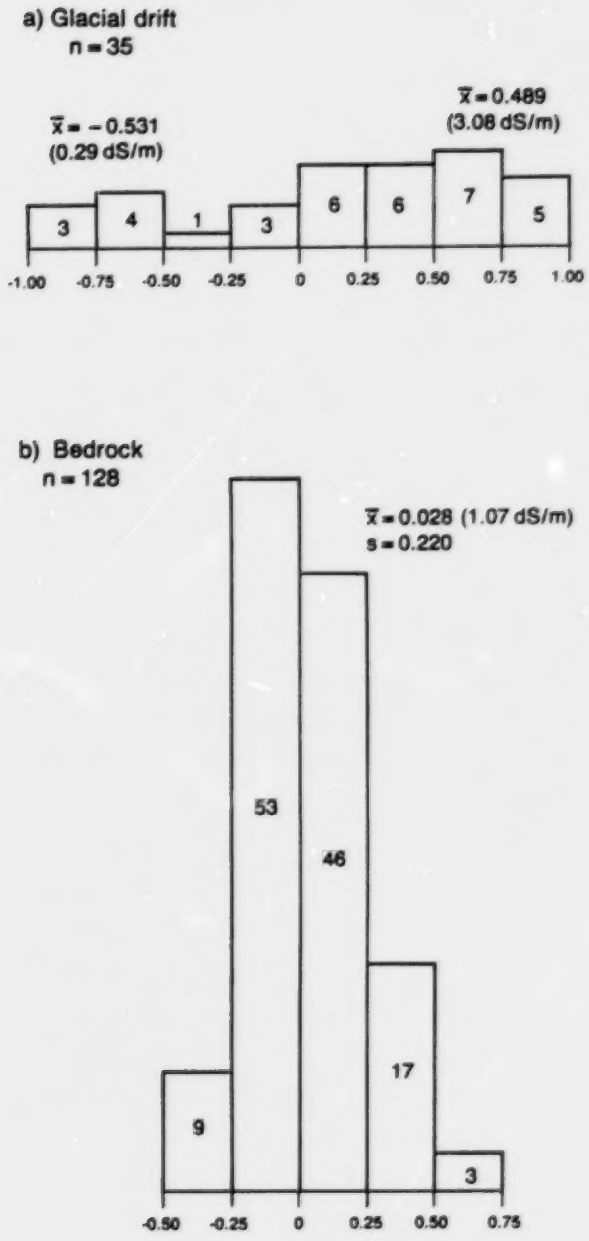

Figure 21. Histogram of electrical conductivity data (base 10 logarithm) from saturation-paste extracts of 35 drift samples and 128 bedrock samples in the Battle River study area.

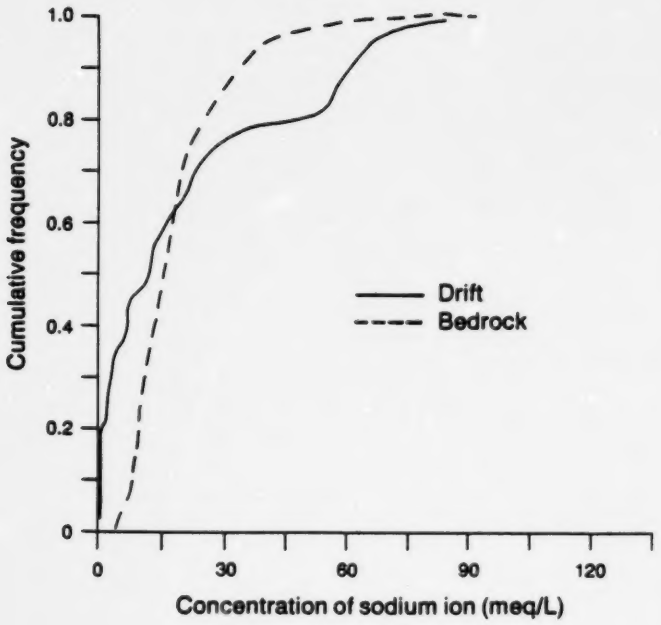

Figure 22. Cumulative frequency distribution of soluble sodium from saturation-paste extracts of 35 drift samples and 128 bedrock samples in the Battle River study area.

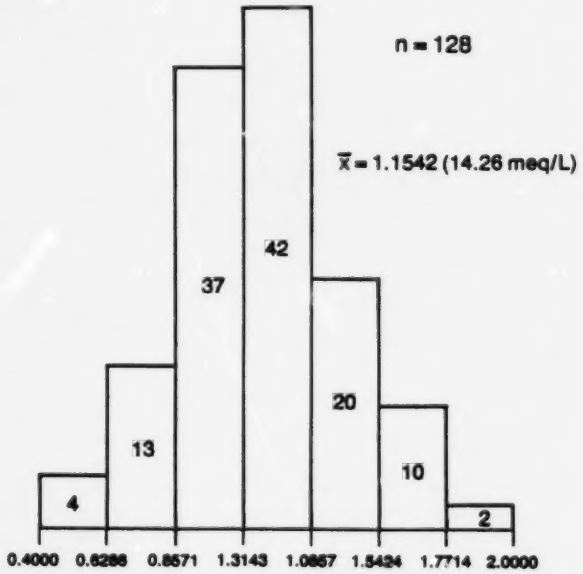

Figure 23. Histogram of soluble sodium (base 10 logarithm) from saturation-paste extracts of 128 bedrock samples in the Battle River study area.

coal-bearing strata. This association may be due to leaching and downward filtering of sodium that originates in stratigraphically higher strata. This sodium could then be concentrated along coal horizons by complexing with organic molecules in the coal or by absorption onto clay minerals within the partings. Alternatively, groundwater passing through the coal aquifers may be bringing in large amounts of sodium from remote strata and concentrating it within the coal beds of the study area.

2.4.5 Soluble Calcium

The concentration of soluble calcium within the 35 glacial drift samples varies between 0.50 meq/L and 32.50 meq/L. The median concentration is 3.50 meq/L (Figure 24). The distribution of the original data is positively skewed and bimodal. When these data are transformed to base 10 logarithms the distribution is less skewed, but still bimodal, with peak means of 1.62 meq/L and 19.37 meq/L (Figure 25a).

The concentration of soluble calcium in 128 samples of bedrock material varies between 0.01 meq/L and 10.07 meq/L (Figure 24). The original data plotted in the form of a histogram are positively skewed. These data, tranformed to base 10 logarithms, yield an approximately normal distribution with a mean of 0.14 meq/L (Figure 25b).

The median values of soluble calcium for the ten bedrock units vary between 0.04 meq/L and 0.21 meq/L. Stratum 7 (Battle River Interval, Cycle III) and Stratum 10 (Battle River Bed) have the highest median concentrations of soluble calcium, 0.21 meq/L and 0.20 meq/L, respectively.

2.4.6 Soluble Magnesium

The concentration of soluble magnesium within glacial drift samples varies between 0.10 meq/L and 18.20 meq/L. The median concentration is 2.30 meq/L (Figure 26).

Soluble magnesium within 128 bedrock samples varies between 0.01 meq/L and 9.55 meq/L. The median concentration is 0.07 meq/L (Figure 26).

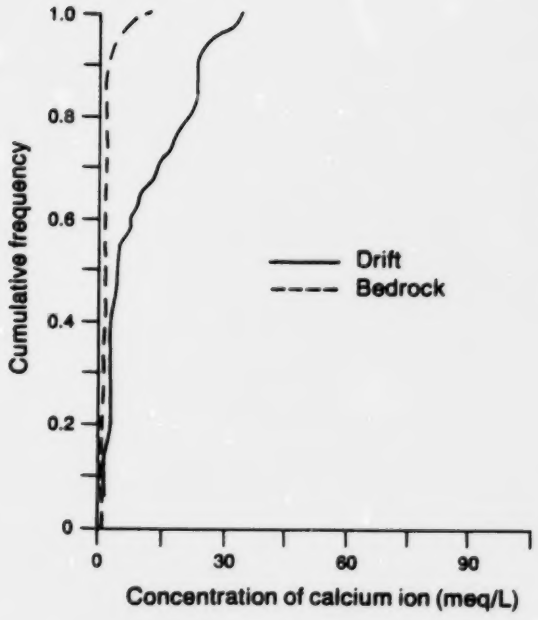

Figure 24. Cumulative frequency distribution of soluble calcium from saturation-paste extracts of 35 drift samples and 128 bedrock samples in the Battle River study area.

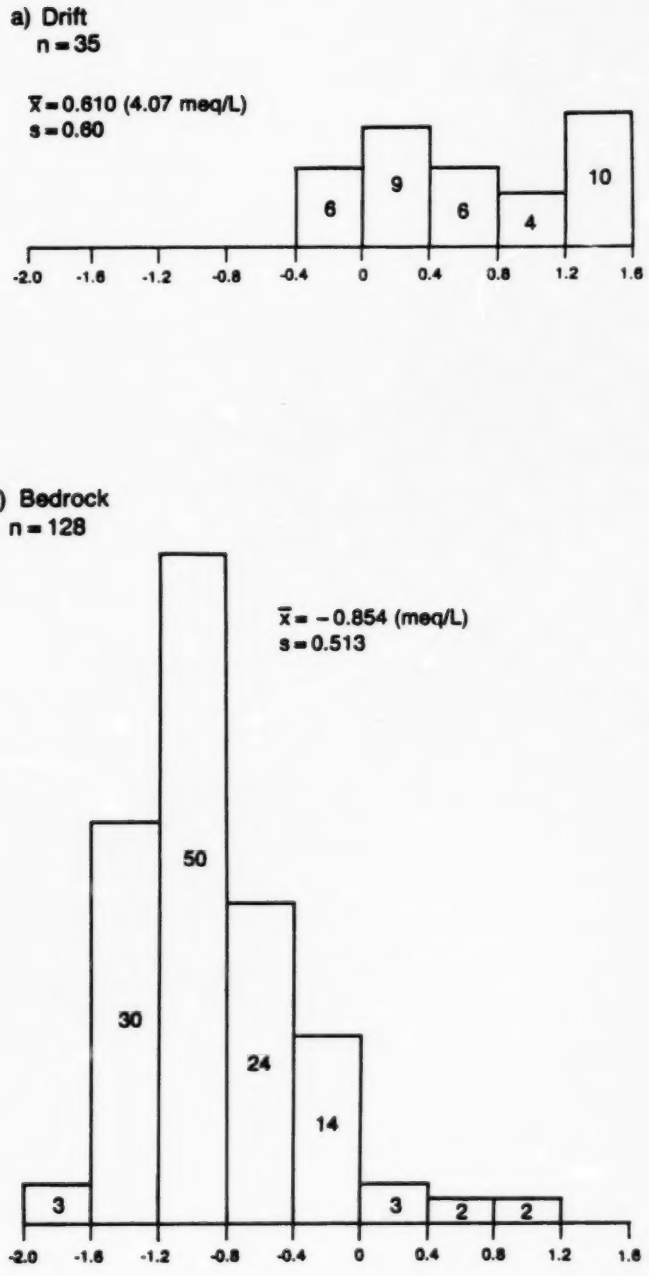

Figure 25. Histogram of soluble calcium (base 10 logarithm) from saturation-paste extracts of 35 drift samples and 128 bedrock samples in the Battle River study area.

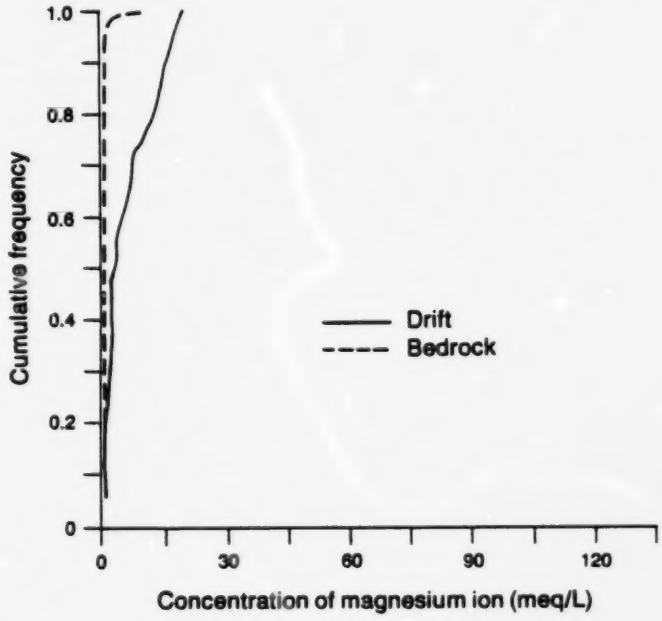

Figure 26. Cumulative frequency distribution of soluble magnesium from saturation-paste extracts of 35 drift samples and 128 bedrock samples in the Battle River study area.

The median concentration of soluble magnesium for each of the ten bedrock units varies between 0.02 meq/L and 0.110 meq/L.

2.4.7 Soluble Potassium

The concentration of soluble potassium within glacial drift samples varies between 0.15 meq/L and 1.64 meq/L. The median concentration is 0.41 meq/L.

Soluble potassium within the 128 bedrock samples varies between 0.16 meq/L and 3.21 meq/L. The median concentration for all bedrock samples is 0.40 meq/L.

The median concentration of soluble potassium for each of the ten bedrock units varies between 0.29 meq/L and 0.60 meq/L.

2.4.8 Sodium Adsorption Ratio

The sodium adsorption ratio (SAR) of 35 glacial drift samples varies between 0.30 and 34.50. The median SAR is 5.0 (Figure 27). Eighty percent of the drift samples have an SAR of less than 15.0.

The SAR of 128 bedrock samples varies between 14.65 and 108.00 (Figure 27). Ninety-nine percent of the bedrock samples have an SAR greater than 15. The SAR values for bedrock samples are normally distributed and have a mean of 46.68 (Figure 28).

The mean SAR for each of the ten bedrock units varies between 39.89 and 63.65. Coal-bearing units and units immediately overlying coal horizons (i.e., Strata 3, 5, 9 and 10) have significantly higher mean SAR values than do the other stratigraphic units.

2.4.9 Soluble Sulfate

The concentration of soluble sulfate ion in extracts from 35 drift samples varies between 0.40 and 106.10 meq/L. The median concentration of sulfate ion in drift samples is 7.5 meq/L (Figure 29). Sixty percent of the samples contain less than 8.1 meq/L sulfate ion. However, 10 percent of the samples contain more than 81 meq/L of sulfate.

The concentration of sulfate ion in 128 extracts from bedrock samples varies between 0.75 and 53.65 meq/L. The median concentration of sulfate ion in bedrock samples is 5.24 meq/L

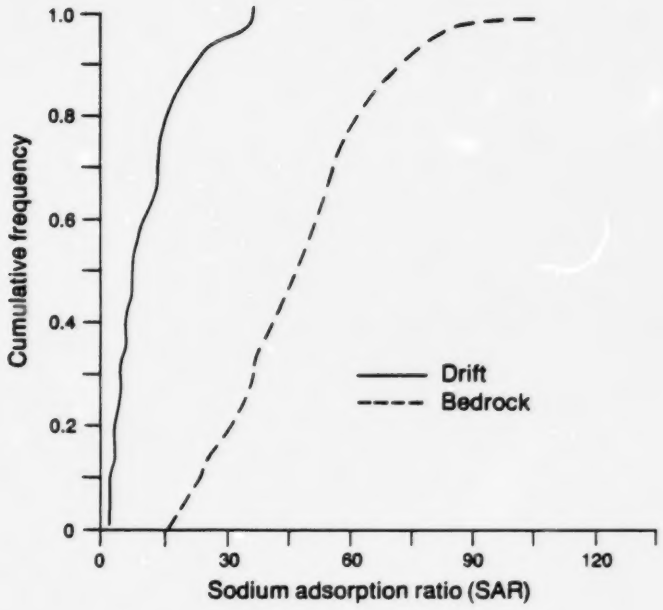

Figure 27. Cumulative frequency distribution of sodium adsorption ratios (sar) calculated from saturation-paste extracts of 35 drift samples and 128 bedrock samples in the Battle River
study area.

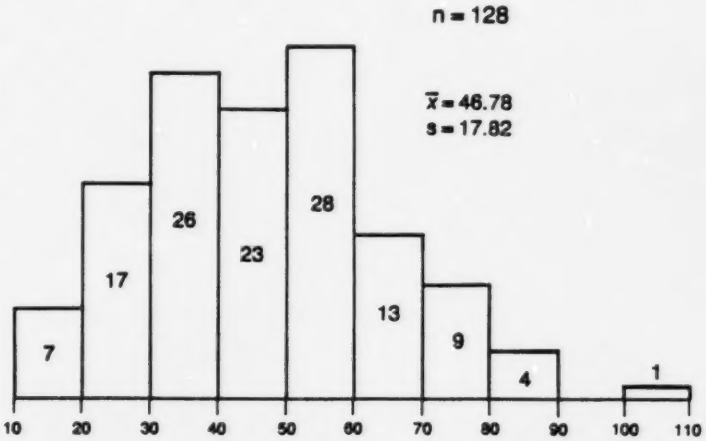

Figure 28. Histogram of sodium adsorption ratios (SAR) calculated from saturation-paste extracts of 128 bedrock samples in the Battle River study area.

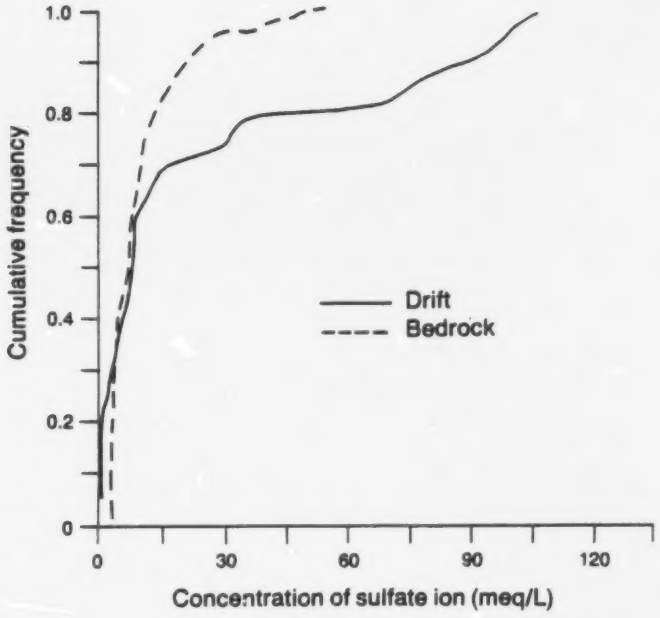

Figure 29. Cumulative frequency distribution of soluble sulfate from saturation-paste extracts of 35 drift samples and 128 bedrock samples in the Battle River study area.

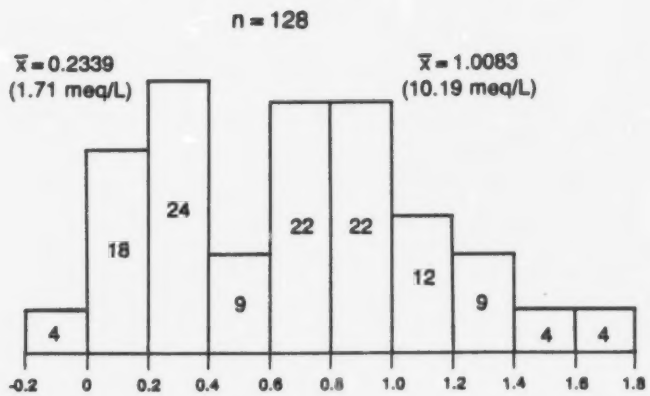

Figure 30. Histogram of soluble sulfate (base 10 logarithm) from saturation-paste extracts of 128 bedrock samples in the Battle River study area.

(Figure 29). Seventy percent of the bedrock samples contain less than 8.7 meq/L soluble sulfate. Bedrock samples lack the high sulfate contents found in a small percentage of the drift samples. Ninety percent of the bedrock samples contain less than 20 meq/L, in contrast to 81 meq/L for the drift. The distribution of the original data is positively skewed, and therefore the data were transformed to base 10 logarithms in order to permit descriptive statistics of the population. The transformed data produced a bimodal distribution with peak means of 1.71 and 10.19 meq/L (Figure 30).

The median value of sulfate ion concentration for each of the ten bedrock units varies between 1.87 meq/L and 15.97 meq/L. Strata 5 (Marker Interval, Basal Shale) and 10 (Battle River Bed) have the highest median concentrations of sulfate, 10.17 meq/L and 15.97 meq/L, respectively.

A strong correlation between soluble sodium and sulfate ions is calculated from the original data for 10 of the 11 stratigraphic units. The correlation coefficient is greater than 0.9 for Strata 2, 3, 5, 9 and 11, and greater than 0.8 for Strata 1, 4, 7 and 8. There is no direct linear correlation between soluble sodium and sulfate within Stratum 10, the Battle River Bed. A correlation coefficient of 0.8951 is calculated for the drift samples and a correlation coefficient of 0.8747 is calculated from the entire population of 128 bedrock analyses for these two variables (Figure 31).

Both soluble sodium and sulfate also show a positive linear relationship with electrical conductivity for drift and bedrock samples (Figures 32, 33); calculated correlation coefficients are between 0.86 and 0.94. It is probable that sodium and sulfate co-exist as a salt that affects the conductivity and salinity of the samples.

Strata 3, 4, 5, 6, and 8 yield negative correlation coefficients of better than 0.72 between pH and concentration of soluble sulfate ion. Scatter plots show clusters of high sulfate-low pH samples and low sulfate-high pH samples (Figure 34). Multiple linear regression of the variables pH, sulfate and carbonate yields R values greater than 0.76 for Strata 3, 4, 5, 6, 8 and 10. The pH

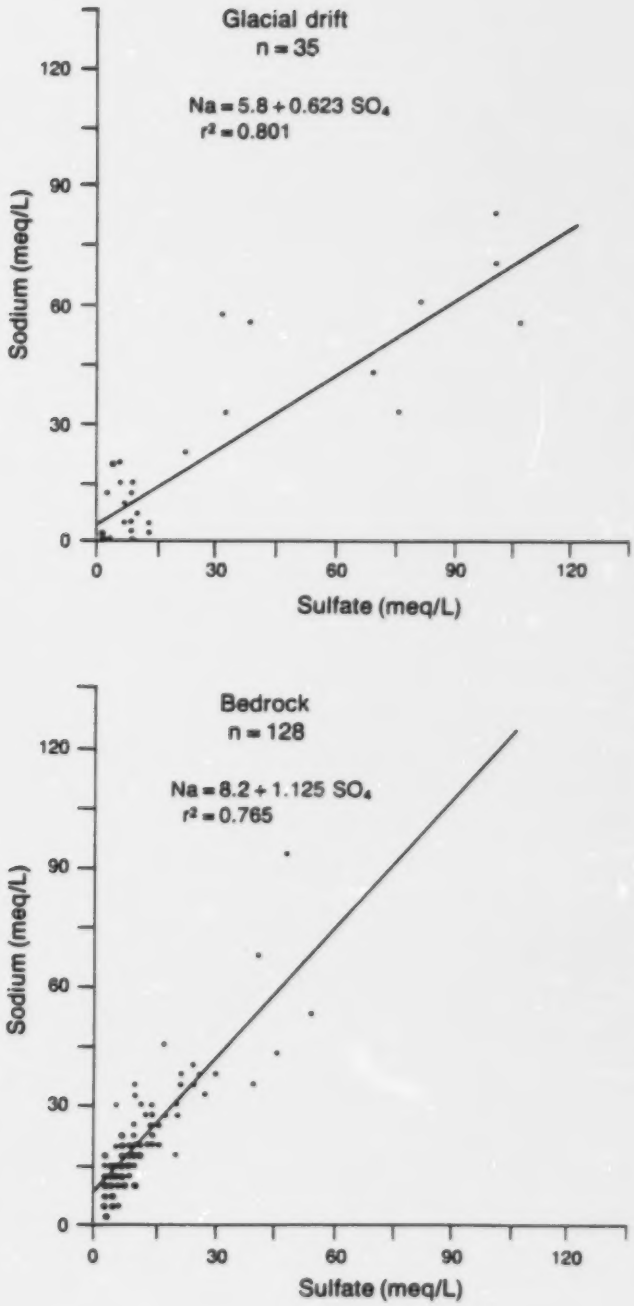

Figure 31. Scatter diagrams showing relationship between soluble sulfate and soluble sodium from saturation-paste extracts of 35 drift samples and 128 bedrock samples in the Battle River study area.

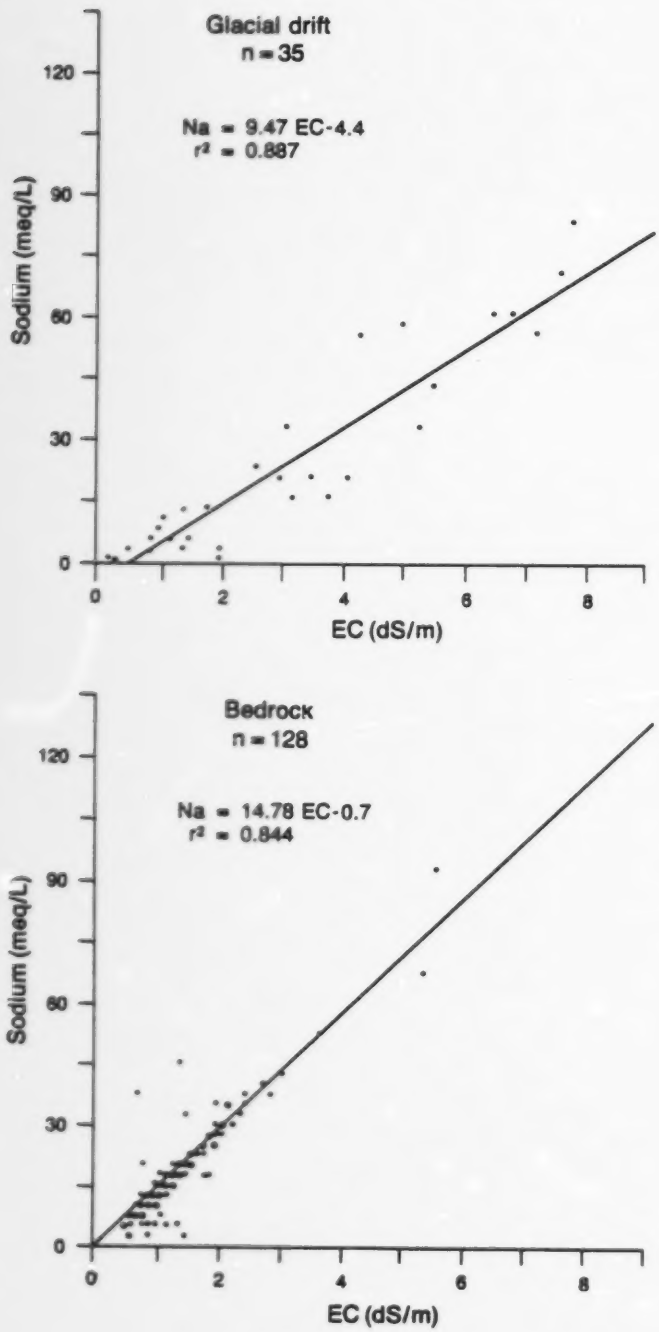

Figure 32. Scatter diagrams showing relationship between electrical conductivity and soluble sodium from saturation-paste extracts of 35 drift samples and 128 bedrock samples in the Battle River study area.

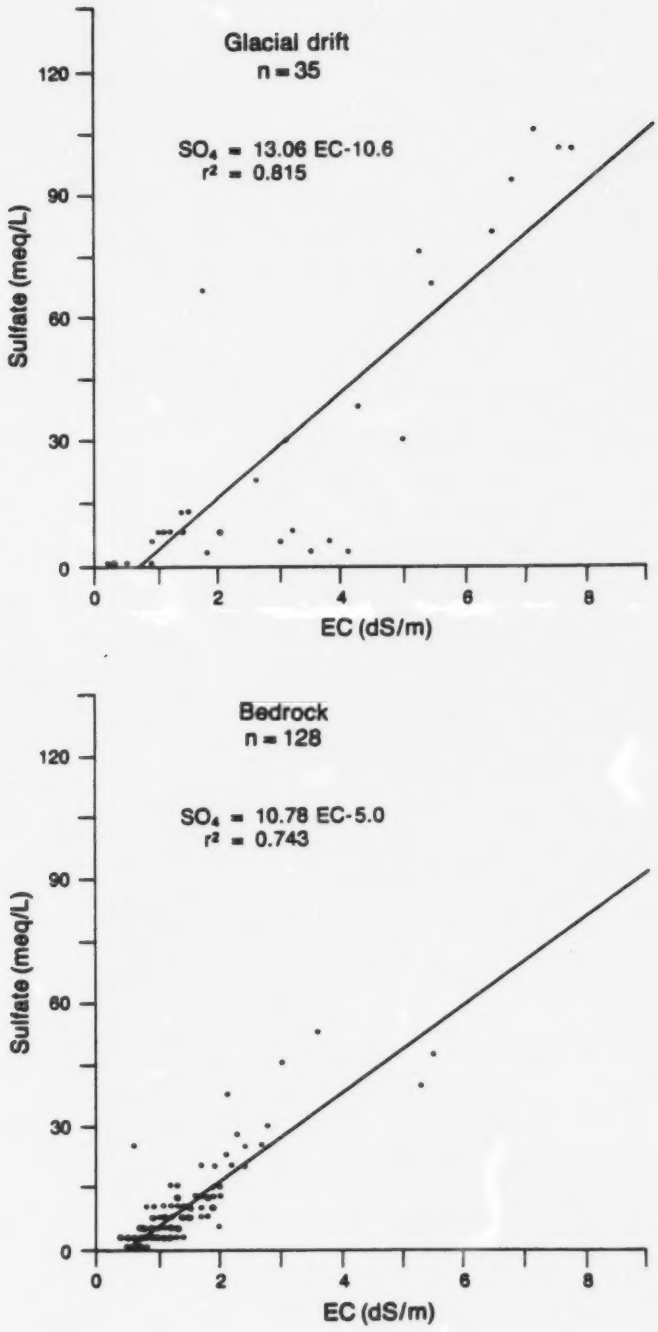

Figure 33. Scatter diagrams showing relationship between electrical conductivity and soluble sulfate from saturation-paste extracts of 35 drift samples and 128 bedrock samples in the Battle River study area.

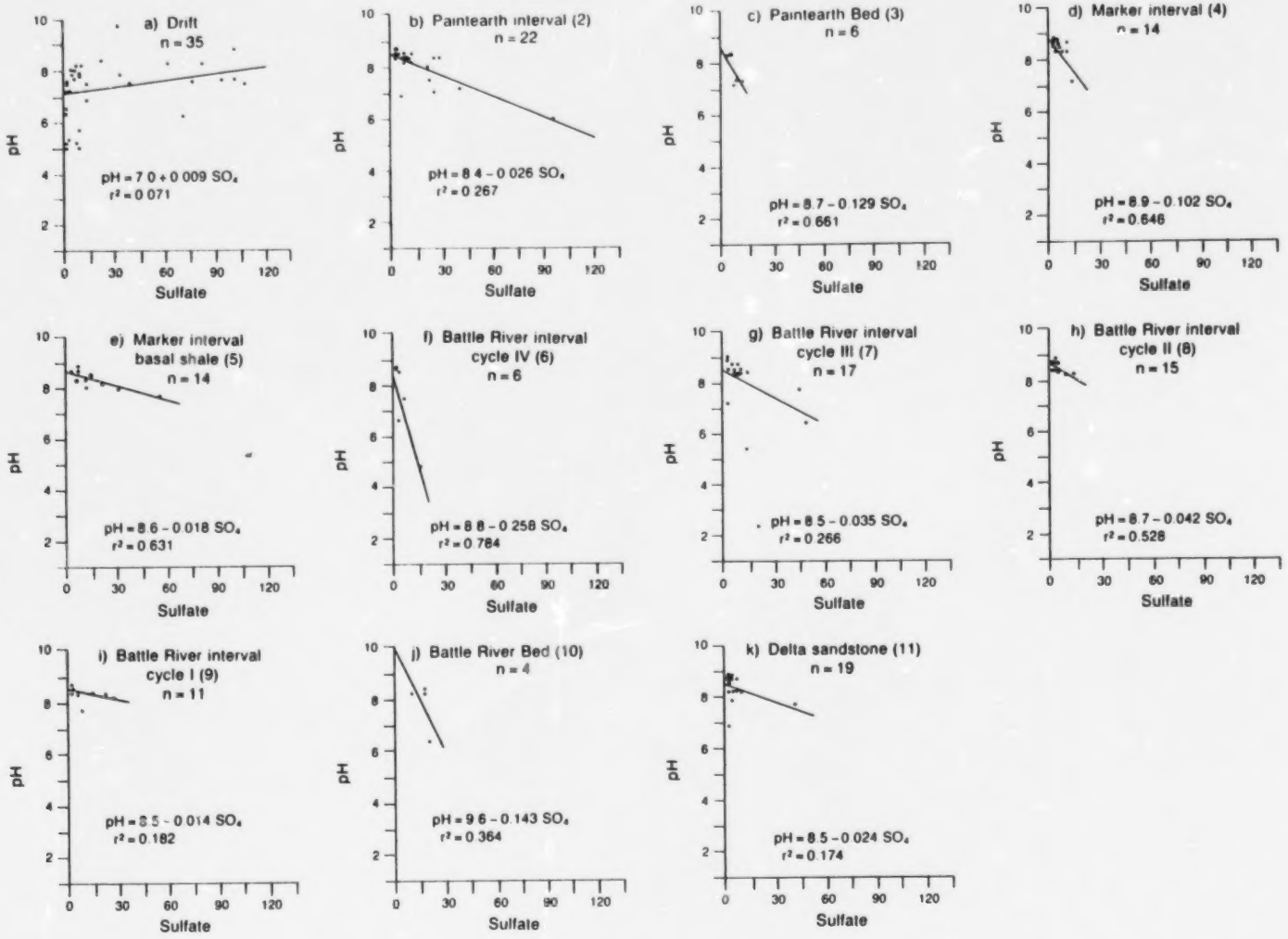
a) Drift
n = 35
pH = 7.0 + 0.009 SO4
r² = 0.071
b) Paintearth interval (2)
n = 22
pH = 8.4 - 0.026 SO4
r² = 0.267
c) Paintearth Bed (3)
n = 6
pH = 8.7 - 0.129 SO4
r² = 0.661
d) Marker interval (4)
n = 14
pH = 8.9 - 0.102 SO4
r² = 0.646
e) Marker interval basal shale (5)
n = 14
pH = 8.6 - 0.018 SO4
r² = 0.631
f) Battle River interval cycle IV (6)
n = 6
pH = 8.8 - 0.258 SO4
r² = 0.784
g) Battle River interval cycle III (7)
n = 17
pH = 8.5 - 0.035 SO4
r² = 0.266
h) Battle River interval cycle II (8)
n = 15
pH = 8.7 - 0.042 SO4
r² = 0.528
i) Battle River interval cycle I (9)
n = 11
pH = 8.5 - 0.014 SO4
r² = 0.182
j) Battle River Bed (10)
n = 4
pH = 9.6 - 0.143 SO4
r² = 0.364
k) Delta sandstone (11)
n = 19
pH = 8.5 - 0.024 SO4
r² = 0.174
pH
Sulfate

Figure 34. Scatter diagrams showing relationship between pH and soluble sulfate in samples from each of the 11 stratigraphic units delineated in the Battle River study area.

appears to be a function of availability of sulfate from the oxidation of pyrite or organic compounds for acid production and carbonate for buffering.

2.4.10 Soluble Bicarbonate

The concentration of bicarbonate ion within 128 extracts from bedrock samples varies between 1.30 meq/L and 67.40 meq/L. The median value is 6.6 meq/L and 90 percent of the sample extracts contain less than 10.8 meq/L bicarbonate. The median concentration of bicarbonate ion for individual bedrock units ranges from 5.30 meq/L to 8.20 meq/L.

2.4.11 Soluble Chloride

The concentration of chloride in 35 extracts from drift samples varies between 0.10 and 1.70 meq/L. The median value is 0.30 meq/L. Eighty percent of the samples contain less than 0.60 meq/L chloride ion.

The concentration of chloride ion in 128 extracts from bedrock samples varies between 0.01 and 7.39 meq/L. Ninety percent of the samples contain less than 1.41 meq/L soluble chloride. The original data plot as a positively skewed histogram. These data were transformed to base 10 logarithms to bring the distribution closer to normal. The transformed data have a bimodal distribution, with peak means of 0.02 meq/L and 0.66 meq/L.

The median concentration of chloride ion within the 10 bedrock units ranges from 0.37 meq/L to 0.76 meq/L.

2.5 Exchangeable Cations

The exchangeable cations were determined on the less than 2 mm fraction of 35 drift samples and 147 bedrock samples following the method of McKeague (1978).

2.5.1 Exchangeable Sodium

The amount of exchangeable sodium in drift samples varies between 0.07 and 20.40 meq/100g. Seventy percent of the drift samples contain less than 4.4 meq/100g of exchangeable sodium (Figure 35). The original data yield a positively skewed

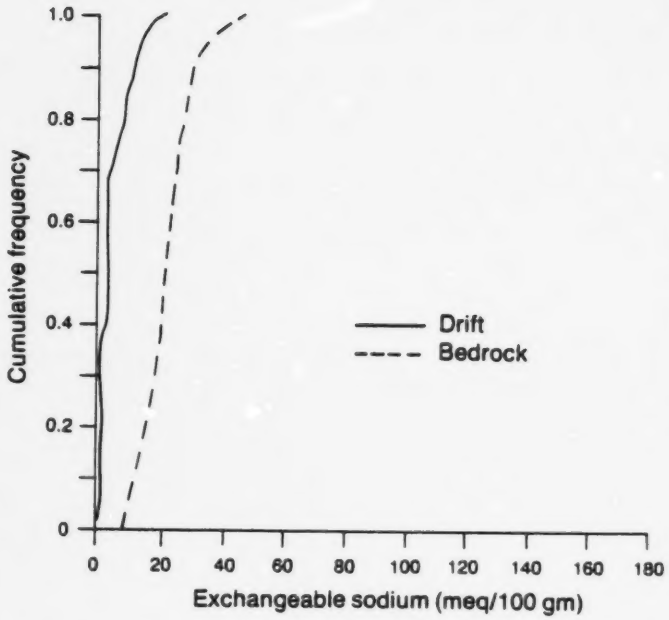

Figure 35. Cumulative frequency distribution of exchangeable sodium determined from 35 drift samples and 147 bedrock samples in the Battle River study area.

distribution. The data transformed to base 10 logarithms produce a bimodal distribution, with peak means of 0.179 and 3.90 meq/100g (Figure 36a).

Exchangeable sodium within bedrock samples varies between 5.17 and 45.07 meq/100g. The median value is 20.15 meq/100g (Figure 35). The data plot as a normal distribution with a mean value of 20.07 meq/100g and a standard deviation of 7.72 meq/100g (Figure 36b).

The median concentration of exchangeable sodium within each of the 10 bedrock units ranges from 16.13 to 31.20 meq/100g. The largest median value, 31.20 meq/100g, corresponds to the Battle River Bed.

Strata 4, 7 and 11 show good positive correlations (>0.7) between the amount of exchangeable sodium and the percentage clay (<0.004 mm) within the sample (i.e., exchangeable sodium increases as percentage clay within the sample increases). A scatter diagram of exchangeable sodium versus percentage fine and coarse clay, including all bedrock samples, clusters the data into a lenticular form with a positive slope (Figure 37). A linear relationship is apparent, however, many data points plot outside the lens. A possible explanation of the scatter may be that the exchangeable sodium was determined on the <2 mm fraction of the sample and, therefore, exchangeable sodium associated with coarser grains and organic compounds is included in the measurement. Despite this situation, it is still reasonable to assign the major portion of the exchangeable sodium to the clays and authigenic zeolites within the samples.

2.5.2 Exchangeable Calcium

Exchangeable calcium in drift samples measures between 1.90 and 45.40 meq/100g. The median value is 14.80 meq/100g (Figure 38). Eighty percent of the drift samples contain less than 24.5 meq/100g exchangeable calcium.

Exchangeable calcium within the bedrock samples varies between 5.68 and 143.88 meq/100g. The median value is 18.38 meq/100g and 90 percent of the samples contain less than 28.2 meq/100g exchangeable calcium (Figure 38). The original data are not normally distributed, but when they are transformed to base 10 logarithms the

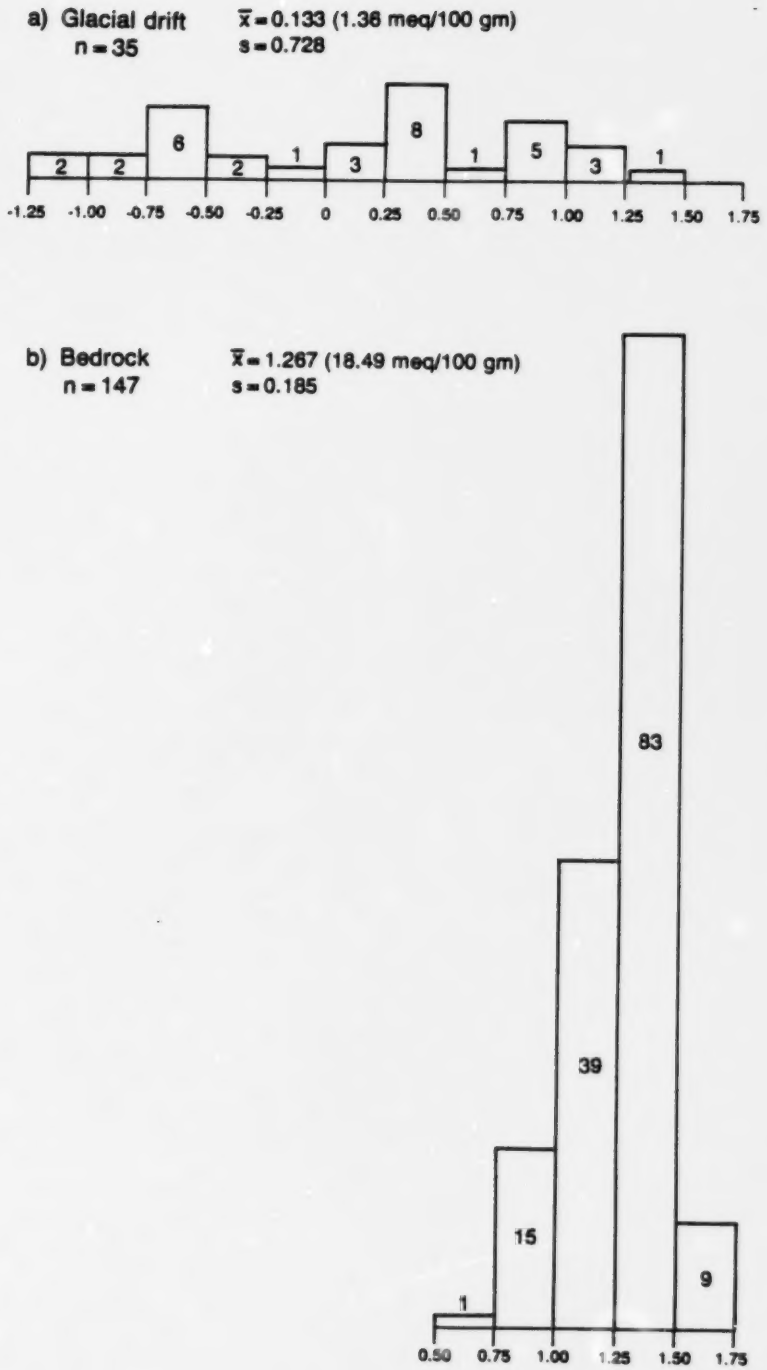

Figure 36. Histogram of exchangeable sodium (base 10 logarithm) determined from 35 drift samples and 147 bedrock samples in the Battle River study area.

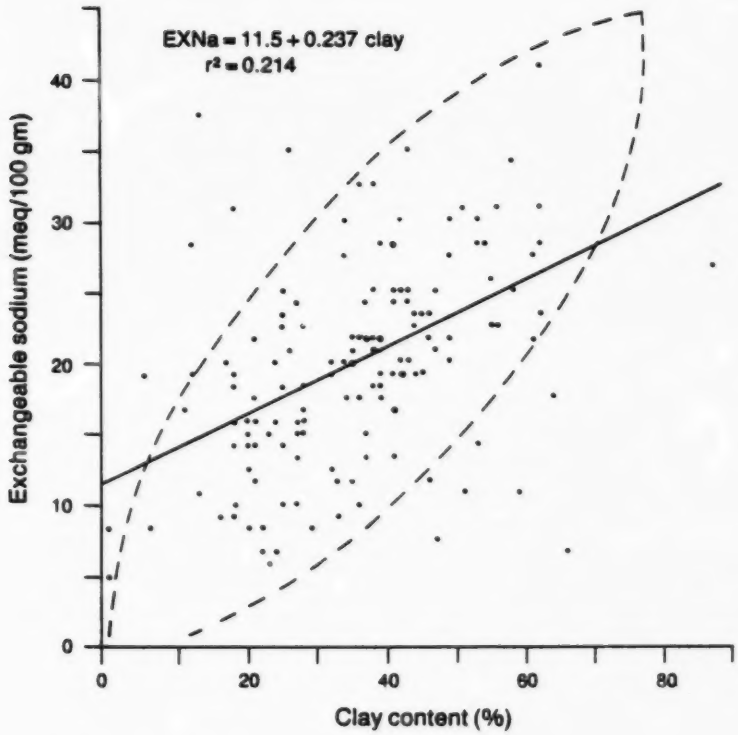

Figure 37. Scatter diagram showing relationship between clay and exchangeable sodium from 147 bedrock samples in the Battle River study area.

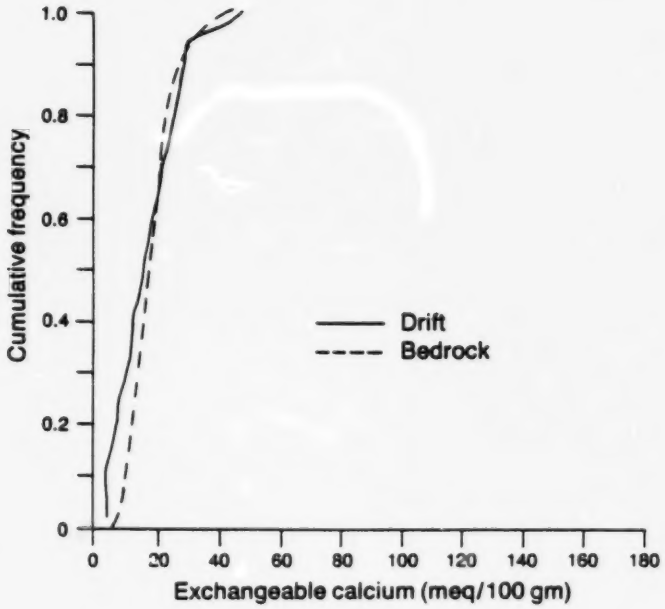

Figure 38. Cumulative frequency distribution of exchangeable calcium determined from 35 drift and 147 bedrock samples in the Battle River study area.

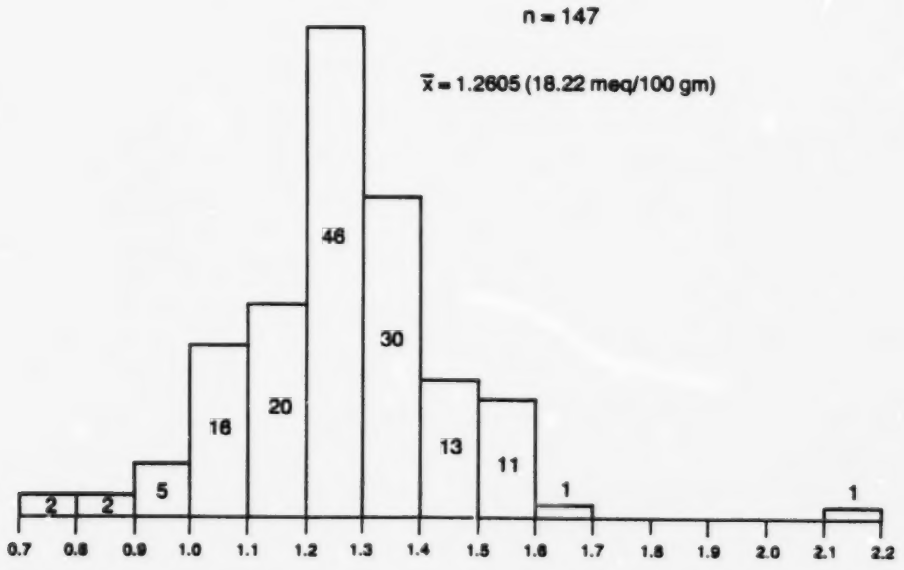

Figure 39. Histogram of exchangeable calcium (base 10 logarithm) determined from 147 bedrock samples in the Battle River study area.

resultant distribution is close to normal and has a mean of 18.22 meq/100g (Figure 39).

The highest median concentration of exchangeable calcium for an individual bedrock unit occurs within the Battle River Bed. This may be the result of preferential flushing out of sodium by groundwater, causing a relative increase in exchangeable calcium.

Stratigraphic units 4, 10 and 11 yield reasonably good positive correlation coefficients (0.7962, 0.7321 and 0.7165, respectively) for exchangeable calcium and percentage clay.

2.5.3 Exchangeable Magnesium

Exchangeable magnesium within drift samples varies between 1.00 and 11.60 meq/100g. The median value is 5.30 meq/100g (Figure 40).

Exchangeable magnesium within bedrock samples varies between 1.03 meq/100g and 12.73 meq/100g (Figure 40). The log mean is 3.45 meq/100g.

2.5.4 Exchangeable Potassium

Exchangeable potassium within drift samples varies between 0.20 and 1.80 meq/100g. The mean amount of exchangeable potassium within these samples is 0.62 meq/100g and the standard deviation is 0.33.

Exchangeable potassium within bedrock samples varies between 0.74 and 3.76 meq/100g. The variable has a normal distribution with a mean of 1.89 meq/100g and a standard deviation of 0.57.

2.5.5 Cation Exchange Capacity

The cation exchange capacity (CEC) was determined for 35 drift samples. The capacity was measured at a fixed pH of 7.0. The CEC of these samples ranges from 6.0 to 33.7 meq/100g. The median value of CEC within the drift samples is 16.60 meq/100g (Figure 41). The original data have a bimodal distribution with a large peak at 14.66 meq/100g and a small peak at 28.80 meq/100g (Figure 42).

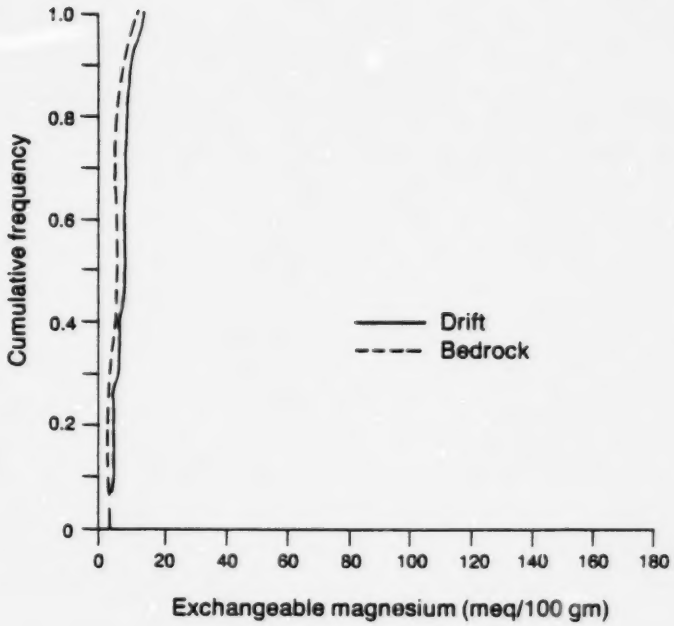

Figure 40. Cumulative frequency distribution of exchangeable magnesium determined from 35 drift samples and 147 bedrock samples in the Battle River study area.

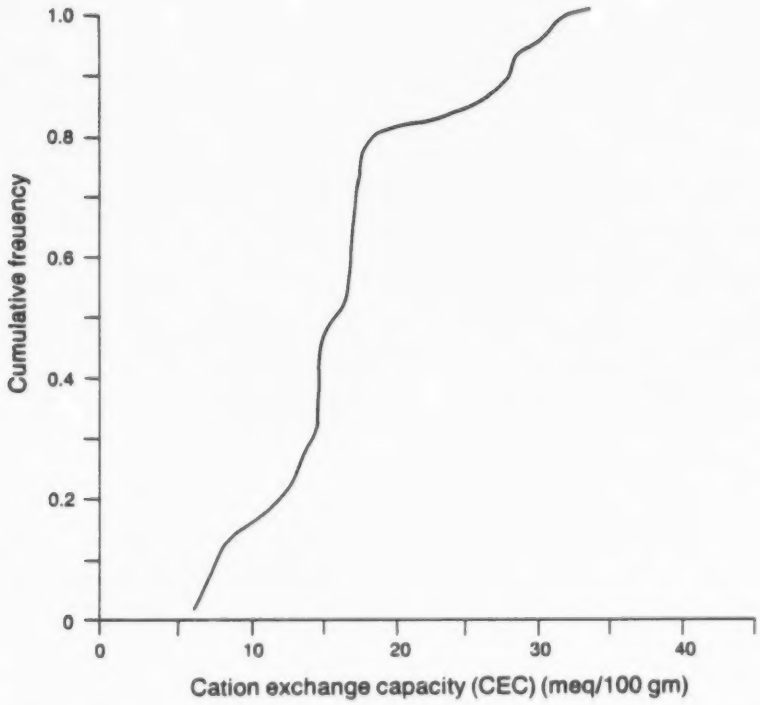

Figure 41. Cumulative frequency distribution of cation exchange capacity (CEC) determined from 35 drift samples in the Battle River study area.

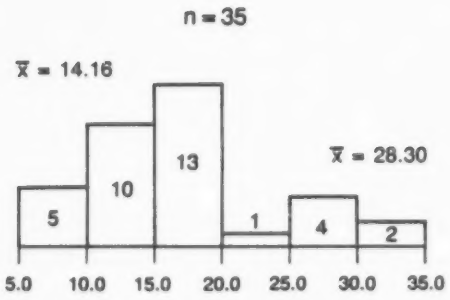

Figure 42. Histogram of cation exchange capacity (CEC) determined from 35 drift samples in the Battle River study area.

3. REFERENCES CITED

McKeague, J.A. 1978. Manual on soil sampling and methods of analysis, Canadian Society of Soil Science.

Statistical Research Laboratory. 1976. Elementary statistics using Midas, University of Michigan.

4 APPENDIX

4.1 Chemical and Physical Analysis of Overburden Samples From the Battle River Study Area

SITE	DEPTH (m)	STRAT.	LITHOLOGY	pH	EC (dS/m)	SAT%	SATURATION EXTRACT Ca	Mg	Na	SO4	HCO3	Cl	K	SAR
							<---------- mg/L ---------->							
5	0.0	1	DRIFT	5.1	.80	59.0	.70	.40	6.20	5.30		.60	.28	8.10
	.50	1	DRIFT	8.3	2.50	119.0	1.50	1.70	22.60	20.60		.10	.41	18.00
	.90	1	DRIFT	6.2	5.42	57.0	23.50	10.70	41.70	68.60		.10	.78	10.10
	1.20	1	DRIFT	7.8	3.00	118.0	2.70	1.70	31.30	31.20		.10	.55	21.10
	1.60	5	SHALE	8.2	1.90	105.7	.80	.59	26.65	20.21	4.10	.65	1.03	32.01
	3.45	6	SHALE	4.8	1.15	75.0	.60	.93	20.43	15.22	2.10	2.99	.96	23.30
	3.64	7	SILTSTONE	5.4	1.35	72.5	.25	.60	21.09	13.23	2.10	1.69	.90	32.19
	3.89	7	SANDSTONE	7.1	.75	159.4	.03	.03	3.00	1.50	1.30	.28	.37	16.26
	5.13	7	SHALE	8.3	.95	184.0	.49	.31	14.57	5.93	7.50	.93	.46	23.02
	5.60	7	SHALE	8.4	1.10	137.5	1.39	.33	17.13	7.74	8.40	1.41	.47	18.47
	7.62	7	SHALE	8.4	1.12	142.9	.21	.14	16.04	7.49	6.50	.85	.40	38.32
	8.74	8	SILTSTONE	8.7	.74	394.0	.04	.03	10.61	2.99	6.40	.48	.32	53.70
	12.91	8	SHALE	8.6	1.10	253.5	.06	.07	14.70	2.99	9.70	.56	.44	58.80
	15.63	10	SHALE	8.4	2.05	206.5	.09	.07	30.65	13.47	11.40	.56	.67	108.00
	19.02	11	SHALE	8.2	1.05	208.2	.10	.02	16.39	1.87	10.00	1.13	.46	65.52
	19.72	11	SANDSTONE	8.1	1.30	133.2	.11	.01	19.04	5.93	8.70	.85	.47	76.71
	20.44	11	SANDSTONE	8.6	.70	216.5	.05	.12	13.74	1.50	6.30	.56	.32	47.03
10	0.0	1	DRIFT	5.0	.78	76.0	3.30	2.30	1.70	.70		.30	.87	1.00
	4.60	1	DRIFT	7.7	3.70	50.0	23.00	18.20	15.70	4.40		.10	.81	3.40
	5.00	1	DRIFT	7.9	4.00	54.0	22.00	18.20	20.90	3.70		.40	.92	4.70
	5.50	1	DRIFT	8.0	3.40	50.0	16.80	12.40	19.10	3.70		.40	.97	5.00
	5.90	1	DRIFT	8.0	2.90	52.0	12.00	6.60	19.10	5.00		.20	.90	6.30
	6.40	1	DRIFT	7.9	3.10	53.0	18.00	9.50	15.70	6.90		.30	.94	4.20
	7.33	8	SANDSTONE											
	9.55	8	SANDSTONE											
	10.50	9	SHALE											
	16.71	11	SHALE											
	17.30	11	SHALE											
	19.10	11	SHALE											

SITE	DEPTH	EXCHANGEABLE CATIONS Ca	Mg	Na	K	CEC	CARBONATE Cal	Dol	Total	Sm	CLAY MINERALOGY Ill	Kaol	Chl
5	0.0	6.00	3.50	2.30	.50	33.7	2.9	1.4	4.4	0	65	35	0
	.50	27.70	11.60	8.80	.80	14.6	8.8	3.6	12.4	55	30	10	5
	.90	13.00	4.30	4.40	.50	18.0	2.0	.6	2.6	40	45	5	10
	1.20	24.50	7.40	10.40	.70	9.4	3.6	3.5	7.1	50	30	15	5
	1.60	25.96	12.73	10.46	2.31		.7	3.5	2.7	45	40	15	0
	3.45	13.85	8.68	9.87	2.05		0.0	1.0	1.0	45	35	20	0
	3.64	15.33	9.38	9.87	1.72		.7	1.9	2.6	65	15	20	0
	3.89	14.65	9.42	10.04	1.23		.1	2.2	2.3	100	0	0	0
	5.13	17.65	9.46	11.96	1.82		0.0	1.9	1.9	85	10	5	0
	5.60	21.10	10.17	14.39	2.10		23.9	3.9	27.8	80	10	10	0
	7.62	15.90	7.93	18.52	1.77		1.4	18.0	19.4	75	20	5	0
	8.47	14.53	4.26	19.28	1.54		0.0	3.7	3.5	100	0	0	0
	12.91	21.85	3.72	28.24	2.54		0.0	9.2	8.3	80	15	5	0
	15.63	22.38	4.09	29.85	2.87		0.0	3.4	2.6	70	20	5	0
	19.02	17.88	3.22	23.07	2.51		0.0	22.0	21.7	65	25	10	0
	19.72	11.73	2.19	16.52	2.05		.1	1.6	1.7	55	25	20	0
	20.44	9.65	1.69	12.28	1.23		1.0	4.5	5.5	95	0	5	0
10	0.0	13.40	4.20	.36	1.10	27.4	.7	1.6	2.3	15	60	25	0
	.90	0.0	0.0	0.0	0.0	0.0	1.9	3.8	5.7	45	40	10	5
	4.60	20.00	5.20	1.30	.40	17.1	1.1	6.0	7.0	45	35	15	5
	5.00	27.30	7.30	2.50	.60	15.1	1.9	4.3	6.3	40	40	15	5
	5.50	17.40	6.40	1.80	.60	13.1	3.6	5.3	8.8	50	35	10	5
	5.90	18.40	5.60	2.30	.60	11.7	3.8	5.2	9.1	45	35	15	5
	6.40	21.40	5.70	2.00	.70	13.4	3.5	4.9	8.4	45	35	15	5
	7.33	143.88	6.36	8.35	1.41		1.1	6.4	7.5	90	5	5	0
	9.55	24.13	8.93	5.74	1.18		1.0	2.6	3.6	100	0	0	0
	10.50	29.85	8.97	6.96	2.31		.2	4.4	4.6	60	25	5	10
	16.71	21.93	3.51	28.02	2.46		.1	6.5	6.6	65	20	15	0
	17.30	15.73	2.56	19.96	2.14		0.0	1.8	1.8	60	25	10	5
	19.10	15.75	2.89	21.78	2.36		.5	1.1	1.6	60	25	0	15

SITE	DEPTH	GRAIN SIZE ANALYSES % FINER (units = micrometers) 2000	1000	500	250	100	63	50	20	10	4	2	SULFUR ISOTOPES Sol S	Insol S	Total S
5	0.0	100	98	Na	Na	Na	70	68	Na	Na	26	20			
	.50	100	100	Na	Na	Na	92	90	Na	Na	56	48			
	.90	100	98	Na	Na	Na	54	52	Na	Na	35	32			
	1.20	100	100	Na	Na	Na	93	92	Na	Na	73	64			
	1.60	100	100	100	100	99	Na	91	76	59	59	Na	.47	.71	
	3.45	100	100	100	100	75	Na	59	38	25	25	Na	2.21	8.66	4.97
	3.64	100	100	100	100	69	Na	57	39	27	27	Na	3.32	6.65	6.61
	3.89	100	100	100	99	43	Na	21	19	18	18	Na	3.65	8.55	7.64
	5.13	100	100	100	100	67	Na	51	39	33	33	Na	2.90	2.48	
	5.60	100	100	100	96	36	Na	24	20	18	18	Na	2.37	3.15	2.52
	7.62	100	100	100	100	99	Na	87	57	39	39	Na	.89	.42	.52
	8.74	100	100	100	100	59	Na	46	34	32	32	Na	2.72	2.74	2.15
	12.91	100	100	100	100	95	Na	84	46	39	39	Na	8.48	1.35	1.72
	15.63	100	100	100	100	90	Na	80	59	34	34	Na	7.56	14.80	13.36
	19.02	100	97	95	94	74	Na	66	56	44	44	Na		4.16	5.82
	19.72	100	100	100	98	63	Na	56	43	28	28	Na	19.56	15.88	17.89
	20.44	100	100	100	85	32	Na	28	23	20	20	Na			
10	0.0	100	97	Na	Na	Na	60	58	Na	Na	18	12			
	.90	100	100	Na	Na	Na	63	57	Na	Na	38	33			
	4.60	100	98	Na	Na	Na	97	94	Na	Na	18	16			
	5.00	100	99	Na	Na	Na	61	57	Na	Na	16	21			
	5.50	100	99	Na	Na	Na	58	55	Na	Na	27	22			
	5.90	100	96	Na	Na	Na	59	56	Na	Na	28	25			
	6.40	100	98	Na	Na	Na	57	54	Na	Na	30	24			
	7.33	100	100	100	90	39	Na	36	29	22	22	Na	-8.35	-2.87	9.65
	9.55	100	100	100	100	43	Na	37	29	23	23	Na	-8.76	-11.30	5.28
	10.50	100	100	100	100	100	Na	100	87	66	66	Na	-9.31	-9.31	-11.67
	16.71	100	100	100	99	80	Na	74	66	54	54	Na	-.21	2.60	1.36
	17.30	100	100	100	82	38	Na	35	30	24	24	Na	.01	4.15	5.50
	19.10	100	100	100	100	95	Na	78	51	36	36	Na	1.87	4.55	4.86

SITE	DEPTH (m)	STRAT.	LITHOLOGY	pH	EC (dS/m)	SAT%	SATURATION EXTRACT Ca	Mg	Na	SO4	HCO3	Cl	K	SAR
							<----------			mg/L		----------	->	
6	0.0	1	DRIFT	5.4	1.70	36.0	1.20	.80	12.20	1.40		.10	.27	11.90
	.50	1	DRIFT	7.5	5.21	82.0	32.50	12.80	31.30	74.90		.30	1.28	6.60
	.90	1	DRIFT	7.3	7.14	103.0	31.20	18.20	55.70	106.10		.10	1.64	11.20
	4.87	4	SHALE	8.4	.78	192.1	.03	.04	11.13	2.81	6.20	.86	.37	56.98
	5.89	5	SHALE	8.3	1.55	239.8	.24	.07	19.26	10.73	6.90	.76	.55	48.58
	7.14	5	SHALE	8.3	1.35	146.2	.15	.08	18.09	5.61	11.30	1.04	.87	53.03
	9.76	5	SHALE	8.5	1.50	106.3	.11	.09	23.65	6.74	12.80	1.04	.54	73.71
	10.14	5	SANDSTONE	8.7	1.15	185.0	.14	.07	16.17	1.68	13.30	.37	.40	49.78
	11.44	6	SHALE	8.5	1.15	182.5	.03	.05	16.04	2.99	10.30	.56	.44	80.20
	14.57	7	SHALE	8.5	1.55	145.5	.16	.08	22.30	8.48	10.50	1.13	.51	63.39
	16.81	8	SHALE	8.3	1.05	192.4	.07	.02	13.85	4.55	6.60	1.04	.41	64.63
	17.76	9	SANDSTONE	8.7	.68	275.8	.10	.09	10.09	1.87	4.90	.76	.31	32.65
	19.18	9	SHALE	7.6	1.40	133.8	.09	.02	19.78	7.99	7.90	.76	.49	83.77
	22.48	11	SHALE	7.8	.71	193.4	.12	.08	11.13	3.74	4.80	1.41	.36	34.54
	23.80	11	SILTSTONE	8.6	.69	333.0	.14	.14	10.83	1.12	7.90	.56	.35	28.65
	24.38	11	SANDSTONE	8.7	.71	312.1	.02	.02	9.48	1.12	6.60	.56	.31	70.13
23	1.00	1	DRIFT	7.2	6.30	55.5	12.77	10.08	81.96	68.62	2.30	.37	1.64	24.25
	5.18	1	DRIFT	8.2	4.25	80.8	4.57	2.27	57.04	37.43	2.90	.37	.88	30.83
	8.39	4	SANDSTONE	8.6	.93	151.6	.14	.18	14.78	8.80	4.80	.56	.77	36.85
	11.95	7	SHALE	8.5	1.30	141.5	.13	.12	18.96	6.24	11.70	.56	.36	54.08
	13.17	7	SHALE	6.3	5.50	99.3	5.40	1.03	91.74	48.03	2.20	.48	1.54	51.13
	14.16	8	SANDSTONE	8.7	.67	215.8	.07	.04	5.48	1.31	7.80	.20	.77	23.22
	16.45	8	SHALE	8.2	1.70	111.9	.26	.18	25.30	12.91	9.90	.48	1.10	53.54
	17.46	8	SHALE											
	19.04	9	SANDSTONE	8.5	1.10	175.5	.15	.09	17.65	2.06	13.40	.51	.64	50.86
	20.44	9	SHALE											
	23.25	11	SHALE	6.9	1.20	156.8	.09	.17	18.74	1.87	10.60	.65	.46	51.94
	23.71	11	SANDSTONE	8.6	1.05	95.9	.09	.07	7.65	2.25	9.40	.65	.37	27.39
	26.01	11	SANDSTONE	8.9	.49	273.2	.03	.01	3.39	.75	5.90	.28	.23	24.52

SITE	DEPTH	EXCHANGEABLE CATIONS Ca	Mg	Na	K	CEC	CARBONATE Cal	Dol	Total	CLAY MINERALOGY Sm	Ill	Kaol	Chl
6	0.0	3.60	1.40	1.60	.30	8.0	1.2	3.0	4.2	35	45	20	0
	.50	45.40	8.40	4.90	.90	7.1	14.7	5.4	20.1	60	30	0	10
	.90	42.70	11.00	8.90	.90	22.8	0.0	0.0	0.0	80	15	0	5
	4.70	26.65	5.45	20.37	2.74		1.4	1.9	3.3	75	20	5	0
	5.90	34.20	4.21	9.57	1.85		6.6	27.2	33.8	70	20	0	10
	7.14	26.48	5.12	21.24	2.31		0.0	6.6	6.2	85	10	5	0
	9.76	21.80	4.21	19.33	2.79		1.3	8.9	7.6	50	30	10	10
	10.14	10.48	2.02	10.89	1.72		0.0	2.4	1.4	60	15	20	5
	11.44	16.05	2.73	18.76	2.31		.4	2.6	2.3	55	25	10	10
	14.57	15.95	3.43	18.89	2.31		0.0	4.6	3.5	70	20	5	5
	16.81	18.58	3.47	22.02	2.33		0.0	1.9	1.2	80	15	0	5
	17.76	12.78	2.36	15.20	1.62		.3	1.8	2.1	100	0	3	0
	19.18	20.30	3.47	22.02	2.33		.7	3.0	3.7	75	15	10	0
	22.48	24.13	3.39	27.07	2.46		1.3	1.2	2.5	75	0	25	0
	23.80	12.98	2.52	17.17	1.85		.2	1.3	1.1	50	20	30	0
	24.38	13.40	2.73	17.61	1.38		.9	1.2	2.1	100	0	0	0
23	1.00	14.53	11.07	7.96	1.33		.9	2.0	2.9	50	35	10	5
	5.18	53.63	10.12	9.48	1.26		0.0	4.1	3.6	45	35	15	5
	8.39	10.98	5.45	11.89	1.23		.5	0.0	.4	85	5	10	0
	11.95	16.18	6.74	11.63	1.41		0.0	20.8	19.7	60	30	0	10
	13.17	16.83	4.71	16.89	1.85		2.0	6.0	8.0	65	25	5	5
	14.16	17.95	3.18	21.45	1.23		11.5	8.2	19.7	100	0	3	0
	16.45	20.55	3.88	22.00	2.23		.3	5.3	5.6	65	0	5	10
	17.46	9.38	3.51	8.00	1.13		2.4	17.3	19.7	65	0	15	0
	19.04	10.67	1.94	11.85	1.00		.3	2.2	2.6	95	5	3	0
	20.44	25.80	4.31	28.15	1.87		0.0	3.2	2.1	100	0	3	0
	23.25	22.03	3.68	27.91	2.23		0.0	3.6	3.5	75	15	10	0
	23.71	10.05	1.86	13.33	1.05		0.0	1.0	.8	90	0	10	0
	26.01	10.55	2.31	15.00	1.00		0.0	5.9	5.7	85	10	5	0

		GRAIN SIZE ANALYSES % FINER(units = micrometers)											SULFUR ISOTOPES		
SITE	DEPTH	2000	1000	500	250	100	63	50	20	10	4	2	Sol S	Insol S	Total S
6	0.0	100	98	Na	Na	Na	63	62	Na	Na	8	8			
	.50	100	100	Na	Na	Na	74	72	Na	Na	54	50			
	.90	100	100	Na	Na	Na	66	59	Na	Na	36	35			
	4.87	100	100	100	100	99	Na	87	60	42	42	Na			
	5.89	100	100	100	100	94	Na	76	44	33	33	Na	8.32	7.72	8.74
	7.14	100	100	100	100	92	Na	86	62	38	38	Na	1.13	-5.46	4.73
	9.76	100	100	100	100	100	Na	90	70	44	44	Na	1.04	.67	.75
	10.14	100	100	100	88	25	Na	22	15	13	13	Na	-13.00	-11.31	-10.60
	11.44	100	100	100	100	96	Na	85	60	41	41	Na		5.15	-11.64
	14.57	100	100	100	100	100	Na	89	61	39	39	Na	3.15	-1.17	
	16.81	100	100	100	100	99	Na	91	52	35	35	Na	1.71	3.94	4.44
	17.76	100	100	100	100	45	Na	38	33	27	27	Na	1.72	.54	1.41
	19.18	100	100	100	100	91	Na	82	56	37	37	Na	13.31	16.62	16.02
	22.48	100	100	100	100	97	Na	93	92	87	87	Na	3.15	10.64	
	23.80	100	100	100	99	66	Na	55	46	34	34	Na	2.12	6.36	4.74
	24.38	100	100	100	89	34	Na	31	26	21	21	Na	9.57	6.27	
23	1.00	100	95	93	82	55	Na	47	32	25	25	Na	-11.46	-8.85	-11.41
	5.18	100	93	90	79	53	Na	43	29	21	21	Na	-12.90	-.44	-10.45
	8.39	100	100	100	89	37	Na	34	28	21	21	Na	-21.67	-23.47	-25.03
	11.95	100	100	100	100	95	Na	76	47	35	35	Na	7.08	-2.14	-4.05
	13.17	100	100	100	100	100	Na	90	63	41	41	Na	.05		-2.34
	14.16	100	100	100	98	45	Na	26	23	21	21	Na	-.12	2.80	-.09
	16.45	100	100	100	100	99	Na	92	65	46	48	Na	3.78	10.17	9.29
	17.46	100	52	28	26	23	Na	16	8	6	6	Na	8.33	13.44	12.13
	19.04	100	100	100	100	63	Na	56	48	46	46	Na	1.66		5.42
	20.44	100	100	100	100	90	Na	69	50	41	41	Na		2.42	1.06
	23.25	100	100	100	98	68	Na	56	44	34	34	Na	4.23	9.00	10.36
	23.71	100	100	100	100	78	Na	66	46	37	37	Na	6.62	4.70	8.92
	26.01	100	100	100	99	74	Na	57	46	37	37	Na	5.52	5.79	6.68

SITE	DEPTH (m)	STRAT.	LITHOLOGY	pH	EC (dS/m)	SAT%	SATURATION EXTRACT Ca	Mg	Na	SO4	HCO3	Cl	K	SAR
							<----------			mg/L			---------->	
9	0.0	1	DRIFT	5.6	1.90	43.0	6.00	2.90	1.10	7.50		.10	.55	.50
	.50	1	DRIFT	6.5	.24	47.0	1.80	1.00	.30	.60		.10	.15	.30
	.90	1	DRIFT	7.1	.24	33.0	1.40	.80	.50	.60		.10	.33	.50
	1.40	1	DRIFT	7.5	.20	34.0	1.00	.60	.40	.50		.10	.40	.50
	1.80	1	DRIFT	7.2	.16	34.0	.70	.40	.40	.40		.40	.31	.60
	2.30	1	DRIFT	7.2	.17	35.0	.70	.40	.40	1.00		.30	.31	.60
	2.70	1	DRIFT	7.5	.35	33.0	1.20	.60	2.50	.60		.10	.29	2.60
	3.20	1	DRIFT	7.5	1.40	54.0	5.40	4.10	5.30	11.90		.30	.40	2.40
	3.80	1	DRIFT	6.9	1.30	55.0	6.90	5.60	2.60	11.50		.60	.38	1.00
	4.10	1	DRIFT	8.2	1.00	47.0	1.20	.80	10.40	6.60		.60	.38	10.20
	5.00	1	DRIFT	7.9	1.30	45.0	1.60	.80	11.30	8.10		.30	.37	10.20
	5.50	1	DRIFT	7.8	1.10	49.0	3.70	1.90	6.10	8.10		.50	.40	3.60
	5.90	1	DRIFT	8.2	.90	64.0	.90	.40	7.80	8.40		.70	.32	9.80
	12.19	4	SHALE											
	17.65	6	SHALE	8.6	.65	363.8	.08	.03	9.04	1.87	5.30	.48	.29	38.04
	18.24	7	SANDSTONE	8.8	.48	310.8	.02	.01	6.61	.75	5.30	.28	.23	55.59
	22.01	7	SHALE	7.7	3.00	136.4	.89	.20	41.39	44.92	2.90	.76	.74	55.58
	24.69	8	SHALE	8.7	.77	344.3	.08	.05	11.43	2.25	7.00	.48	.31	44.08
	26.73	9	SANDSTONE	8.6	.57	354.0	.06	.05	8.13	.94	5.30	.37	.26	33.97
	27.59	9	SILTSTONE	8.6	.69	313.7	.11	.07	10.17	.75	7.80	.48	.31	34.28
	28.23	9	SANDSTONE	8.3	2.10	130.3	.56	.31	35.26	21.33	9.20	.93	1.03	53.19
	29.73	10	SANDSTONE											
	30.13	11	SANDSTONE	8.9	.57	274.9	.06	.04	8.57	1.88	6.80	.66	.27	38.95
49	0.0	1	DRIFT	5.0	1.85	46.0	8.90	4.50	1.30	8.10		.80	.35	.50
	.50	1	DRIFT	6.3	.13	51.0	.50	.10	.70	.60		.10	.35	1.20
	.90	1	DRIFT	5.2	.18	47.0	.50	.10	.70	.40		.30	.33	1.20

SITE	DEPTH	EXCHANGEABLE CATIONS Ca	Mg	Na	K	CEC	CARBONATE Cal	Dol	Total	Sm	CLAY MINERALOGY Ill	Kaol	Chl
9	0.0	7.50	1.90	.20	.40	29.4	1.1	1.8	2.9	15	65	10	10
	.50	10.70	5.00	.20	.40	26.6	1.7	2.2	3.9	45	35	10	10
	.90	4.20	1.70	.10	.30	30.5	1.9	1.2	3.1	45	40	10	5
	1.40	2.60	1.10	.10	.20	16.8	1.0	1.5	2.6	60	30	5	5
	1.80	2.20	1.00	.09	.20	27.7	3.5	.9	4.4	60	30	5	5
	2.30	1.90	1.00	.07	.20	8.0	1.6	1.4	3.0	70	25	0	5
	2.70	2.60	1.00	.24	.20	6.0	.4	2.3	2.7	65	25	10	0
	3.20	11.60	6.50	.93	.40	14.3	.5	2.7	3.2	40	35	20	5
	3.80	10.40	6.00	.44	.40	17.1	1.2	1.5	2.7	30	40	25	5
	4.10	15.00	5.70	2.90	.50	14.2	2.0	3.6	5.6	30	45	20	5
	5.00	15.70	4.20	2.00	.50	14.6	1.7	4.0	5.7	45	35	15	5
	5.50	19.40	5.30	1.30	.50	17.7	2.0	3.1	5.0	50	35	10	5
	5.90	14.80	4.10	2.30	.50	17.4	1.5	.8	2.3	50	30	15	5
	12.19	27.53	4.21	25.54	2.54					85	10	0	5
	17.65	13.78	2.40	16.46	2.51		.4	1.2	1.6	0	0	0	0
	18.24	15.90	2.27	18.07	1.28		1.0	2.4	3.4	95	0	5	0
	22.01	18.08	2.40	21.41	2.33		1.0	1.8	2.8	65	20	5	10
	24.69	19.07	3.18	24.50	2.31		.4	4.2	4.6	80	15	0	5
	26.73	18.90	2.48	24.11	1.62		.3	2.1	2.3	100	0	0	0
	27.59	21.48	3.26	24.46	1.90		.1	2.2	2.3	100	0	0	0
	28.23	22.70	3.43	23.41	1.33		.6	4.7	5.3	100	0	0	0
	29.73	19.47	3.51	21.41	1.31					90	0	10	0
	30.12	16.65	2.98	16.15	1.15		1.4	10.0	11.3	100	0	0	0
49	0.0	6.50	1.70	.20	1.80	13.1	2.1	1.2	3.3				
	.50	9.20	3.10	.30	1.10	15.7	2.1	1.4	3.5	45	40	15	0
	.90	9.60	2.90	.20	.70	14.3	2.8	2.3	5.2	45	40	10	5

SITE	DEPTH	GRAIN SIZE ANALYSES % FINER (units = micrometers) 2000	1000	500	250	100	63	50	20	10	4	2	SULFUR ISOTOPES Sol S	Insol S	Total S
9	0.0	100	99	Na	Na	Na	84	83	Na	Na	7	6			
	.50	100	100	Na	Na	Na	57	54	Na	Na	23	18			
	.90	100	99	Na	Na	Na	32	30	Na	Na	9	8			
	1.40	100	100	Na	Na	Na	11	10	Na	Na	7	5			
	1.80	100	100	Na	Na	Na	86	86	Na	Na	7	7			
	2.30	100	100	Na	Na	Na	22	7	Na	Na	9	4			
	2.70	100	100	Na	Na	Na	57	55	Na	Na	32	24			
	3.20	100	100	Na	Na	Na	89	88	Na	Na	50	36			
	3.80	100	99	Na	Na	Na	75	73	Na	Na	36	27			
	4.10	100	99	Na	Na	Na	58	56	Na	Na	30	25			
	5.00	100	98	Na	Na	Na	58	55	Na	Na	28	23			
	5.50	100	99	Na	Na	Na	60	57	Na	Na	32	28			
	5.90	100	99	Na	Na	Na	61	57	Na	Na	32	29			
	12.19	100	100	100	100	100	Na	90	71	55	55	Na			
	17.65	100	100	100	100	96	Na	82	59	41	41	Na			
	18.24	100	100	100	100	42	Na	38	30	25	25	Na			
	22.01	100	100	100	100	100	Na	97	78	48	48	Na			
	24.69	100	100	100	100	100	Na	94	66	43	43	Na			
	26.73	100	100	100	100	84	Na	68	45	37	37	Na			
	27.59	100	100	100	100	100	Na	92	61	41	41	Na			
	28.23	100	100	99	99	34	Na	30	27	25	25	Na			
	29.73	100	100	100	100	99	Na	85	51	38	38	Na			
	30.13	100	100	100	84	36	Na	29	25	20	20	Na			
49	0.0	100	92	Na	Na	Na	49	46	Na	Na	10	8			
	.50	100	99	Na	Na	Na	61	58	Na	Na	29	25			
	.90	100	99	Na	Na	Na	60	56	Na	Na	29	26			

SITE	DEPTH (m)	STRAT.	LITHOLOGY	pH	EC (dS/m)	SAT%	SATURATION EXTRACT Ca	Mg	Na	SO4	HCO3	Cl	K	SAR
							<—— mg/L ——						—>	
24	2.74	1	DRIFT	7.9	4.40	47.3	11.52	5.29	43.83	33.06	2.70	.65	1.42	15.12
	7.01	4	SHALE	7.1	1.35	105.4	.13	.22	19.26	12.48	4.60	.57	.96	45.84
	7.56	4	SANDSTONE	8.3	1.20	156.5	.19	.18	16.91	9.23	5.60	.04	.64	39.23
	7.97	4	SILTSTONE	8.9	.53	270.4	.05	.04	3.05	1.12	4.40	.01	.24	38.33
	9.08	4	SILTSTONE	8.9	.43	338.0	.04	.06	5.39	2.25	3.00	.01	.21	24.13
	10.97	5	SHALE	7.7	3.60	99.6	2.33	.76	52.30	53.65	3.90	.03	1.06	42.04
	13.72	5	SHALE	8.5	1.75	119.8	.15	.17	27.13	13.16	10.10	.03	.60	66.94
	14.34	5	SANDSTONE	8.0	1.85	113.5	.32	.27	29.39	10.17	10.80	.05	1.09	53.76
	14.59	6	SHALE	7.5	.85	145.4	.09	.06	13.52	6.24	3.70	.03	.44	50.07
	15.85	7	SILTSTONE	9.0	.38	255.8	.08	.07	5.48	1.87	1.80	.02	.45	19.72
	17.65	7	SHALE	8.5	.85	138.8	.11	.06	9.48	1.87	6.80	.02	.36	32.72
	19.51	8	SANDSTONE	8.6	.50	259.5	.11	.07	6.91	1.50	3.90	.02	.51	22.47
	22.18	8	SHALE	8.3	1.10	120.5	.20	.10	6.17	5.24	8.70	.03	.77	41.47
	23.98	8	SHALE											
	26.03	9	SILTSTONE											
	28.60	11	SHALE	8.6	.93	188.9	.12	.02	5.78	1.50	9.10	.01	.40	21.13
	29.66	11	SHALE	8.5	1.40	154.5	.07	.01	3.48	1.31	6.90	.01	.46	17.05
	30.02	11	SANDSTONE	8.7	.80	186.5	.05	.03	4.39	1.12	7.30	.01	.32	22.58

SITE	DEPTH	EXCHANGEABLE CATIONS Ca	Mg	Na	K	CEC	CARBONATE Cal	Dol	Total	Sm	CLAY MINERALOGY Ill	Kaol	Chl
24	2.74	16.10	9.63	4.63	1.05		0.0	3.4	2.8	50	35	5	10
	7.01	25.30	5.50	20.15	2.13		0.0	1.7	.9	75	20	5	0
	7.56	17.78	3.47	14.85	1.26		0.0	1.8	.2	100	0	0	0
	7.97	33.05	5.00	32.50	2.03		.4	1.0	1.3	100	0	0	0
	9.08	19.50	2.73	21.37	1.31		.4	1.6	2.0	100	0	0	0
	10.97	17.40	3.10	22.24	2.13		.2	6.3	6.5	55	30	5	10
	13.72	24.13	4.38	14.33	1.69		4.1	22.9	27.0	50	30	5	15
	14.34	6.23	1.28	7.46	1.03		.8	3.1	4.0	60	5	30	5
	14.59	18.39	3.14	21.93	2.28		1.2	2.2	3.4	45	30	10	15
	15.85	15.33	2.36	18.41	1.15		1.2	1.9	3.1	100	0	0	0
	17.65	17.53	3.55	21.37	2.15		.4	5.0	5.4	70	20	5	5
	19.51	19.50	3.02	22.41	1.38		1.6	2.8	4.4	100	3	3	0
	22.18	21.20	3.55	24.83	1.90		1.5	5.1	6.6	90	10	3	0
	23.98	18.50	2.69	22.76	1.74		1.2	2.4	3.6	75	15	0	10
	26.03	27.88	4.17	32.39	1.62					100	0	0	0
	28.60	21.65	3.43	27.96	2.36		0.0	2.1	1.8	70	20	10	0
	29.66	18.45	2.93	22.76	1.90		0.0	1.9	1.2	75	20	0	5
	30.02	12.25	2.15	14.13	.92		0.0	1.5	.9	100	0	0	0

		GRAIN SIZE ANALYSES % FINER (units = micrometers)											SULFUR ISOTOPES		
SITE	DEPTH	2000	1000	500	250	100	63	50	20	10	4	2	Sol S	Insol S	Total S
24	2.74	100	74	71	62	35	Na	13	1	-5	15	Na	*	-8.50	-10.13
	7.01	100	100	100	100	98	Na	82	60	49	49	Na	-1.61	3.36	2.77
	7.56	100	100	100	76	31	Na	26	21	20	20	Na		1.25	4.31
	7.97	100	100	100	100	86	Na	72	48	38	38	Na			
	9.08	100	100	100	100	62	Na	50	40	37	37	Na	4.30	3.20	7.54
	10.97	100	100	100	100	98	Na	86	73	55	55	Na	4.20	4.38	5.18
	13.72	100	98	97	97	94	Na	83	66	53	53	Na	1.14	-2.59	1.74
	14.34	100	100	100	93	74	Na	67	55	47	47	Na	-5.92	2.61	1.07
	14.59	100	99	99	99	95	Na	87	76	61	61	Na		-1.89	-1.38
	15.85	100	100	100	100	45	Na	38	31	28	28	Na	.73	1.63	.74
	17.65	100	100	100	100	100	Na	95	67	49	49	Na	-.24	-.02	
	19.51	100	100	100	100	39	Na	34	26	25	25	Na		3.87	2.87
	22.18	100	100	100	100	99	Na	88	50	38	38	Na	-.50	4.67	3.28
	23.98	100	97	96	94	73	Na	55	38	28	28	Na	1.50	4.04	5.42
	26.03	100	99	99	99	93	Na	67	47	36	36	Na	13.18	18.62	18.41
	28.60	100	100	100	99	96	Na	78	65	53	53	Na			7.33
	29.66	100	100	100	100	97	Na	81	58	44	44	Na		9.28	11.64
	30.02	100	100	100	61	30	Na	24	21	20	20	Na	1.61		4.16

SITE	DEPTH (m)	STRAT.	LITHOLOGY	pH	EC (dS/m)	SAT%	SATURATION EXTRACT Ca	Mg	Na	SO4	HCO3	Cl	K	SAR
							←			mg/L			→	
25	.80	1	DRIFT	7.8	6.80	71.2	5.05	5.87	99.35	58.64	1.80	.02	1.36	41.74
	4.35	2	SANDSTONE	8.4	2.30	114.1	.47	.52	31.70	27.57	4.10	.01	.59	45.04
	4.95	2	SILTSTONE	8.4	.86	159.4	.11	.07	10.83	8.55	3.20	.01	.33	36.48
	5.91	2	SILTSTONE	8.2	.68	238.9	.18	.21	9.26	5.74	3.10	.01	.27	20.84
	8.18	2	SILTSTONE	8.5	.30	117.4	.13	.03	17.91	9.86	6.20	.02	.46	63.96
	9.84	2	SILTSTONE	8.5	.89	181.4	.05	.03	12.70	6.24	4.40	.01	.32	60.50
	11.53	2	SHALE	8.6	.60	298.9	.05	.04	8.22	1.68	5.90	.02	.67	37.28
	12.09	2	SANDSTONE	8.4	.78	200.2	.09	.02	11.61	1.58	8.30	.28	.31	50.30
	14.18	2	SANDSTONE	8.5	.72	212.1	.05	.01	9.78	1.87	6.30	.51	.24	55.00
	16.01	2	SHALE											
	17.63	3	SHALE											
	21 52	4	SANDSTONE	8.7	.52	453.5	.05	.02	6.91	1.50	5.30	.08	.22	37.90
	23.10	4	SANDSTONE	8.5	.65	249.4	.05	.01	8.52	1.50	6.40	.08	.24	49.93
	23.77	5	SHALE	8.5	1.90	116.0	.25	.11	25.30	13.60	8.20	1.41	.56	59.44
	27.50	5	SANDSTONE											
	27.93	6	SILTSTONE	8.6	.66	172.6	.04	.01	10.00	1.62	6.90	.42	.32	63.30
	29.92	7	SHALE	8.3	1.60	155.0	.19	.10	21.39	12.98	6.20	.62	.45	55.78
	32.69	8	SANDSTONE	8.6	.80	232.8	.12	.07	11.70	1.31	8.10	.42	.31	37.83
	35.05	8	SHALE	8.8	.56	274.9	.06	.02	7.04	2.25	3.70	.37	.23	36.01
	37.91	9	SHALE	8.6	.68	231.1	.05	.01	9.57	1.87	6.00	.08	.28	53.78
	42.05	11	SANDSTONE	8.7	.82	212.9	.09	.04	10.87	5.99	4.10	.56	.26	42.42
	43.30	11	SILTSTONE	8.8	.60	402.5	.07	.04	7.26	2.62	4.60	.28	.22	30.11
	44.02	11	SANDSTONE	8.9	.51	322.4	.06	.03	5.78	1.68	4.40	.20	.19	26.81

SITE	DEPTH	EXCHANGEABLE CATIONS Ca	Mg	Na	K	CEC	CARBONATE Cal	Dol	Total	Sm	CLAY MINERALOGY Ill	Kaol	Chl
25	.80	6.48	12.11	9.91	1.64		.8	2.7	3.5	35	45	5	15
	4.35	46.13	6.16	6.96	1.41		.2	3.1	3.4	40	40	15	5
	4.95	16.23	4.96	9.11	1.10		0.0	1.8	1.7	100	0	0	0
	5.91	21.65	10.00	18.46	2.56		1.0	1.0	1.1	60	30	10	0
	8.18	19.30	4.55	18.78	1.54		.2	1.4	1.5	70	20	10	0
	9.84	16.40	3.26	21.74	2.36		.9	2.3	3.2	100	0	0	0
	11.53	27.28	2.36	30.35	1.97		2.0	2.4	4.4	90	0	5	0
	12.09	20.30	2.73	24.87	2.31		14.7	5.7	20.5	90	5	0	5
	14.18	10.70	1.65	20.30	2.00		.2	3.0	3.2	100	0	0	0
	16.01	37.60	2.73	23.59	2.05		46.7	2.5	49.2	90	10	3	0
	17.63	35.85	4.01	44.33	2.13					0	100	0	0
	21.52	14.90	2.27	17.61	1.26		.8	1.5	2.4	100	0	0	0
	23.10	28.20	3.93	33.98	1.88		.4	2.6	3.1	95	5	3	0
	23.77	18.83	3.06	22.37	2.13		.2	2.3	2.5	60	30	10	0
	27.59	9.03	1.94	10.89	2.56		.5	2.9	3.3	50	25	25	0
	27.93	16.40	2.60	20.61	1.41		.2	2.6	2.5	60	25	5	10
	29.92	15.18	3.55	19.37	2.05		.3	3.8	4.1	70	20	5	5
	32.69	16.45	2.64	20.43	2.05		.9	4.8	5.7	100	0	0	0
	35.05	22.48	3.55	29.67	1.33		0.0	2.4	2.5	70	20	10	0
	37.91	22.20	4.46	27.43	2.51		.4	5.8	6.2	95	0	5	0
	42.05	11.43	2.36	15.91	2.23		.4	1.8	2.2	100	0	3	0
	43.30	19.25	3.31	28.07	1.08		.1	1.0	1.2	100	0	3	0
	44.02	11.45	2.19	15.93	1.77		0.0	2.7	2.4	100	0	0	0

SITE	DEPTH	GRAIN SIZE ANALYSES % FINER (units = micrometers) 2000	1000	500	250	100	63	50	20	10	4	2	SULFUR ISOTOPES Sol S	Insol S	Total S
25	.80	100	89	83	77	62	Na	44	30	23	23	Na			
	4.35	100	96	94	85	58	Na	45	30	22	22	Na			
	4.95	100	100	100	98	31	Na	26	20	18	18	Na			
	5.91	100	100	100	99	47	Na	29	22	18	18	Na			
	8.18	100	100	100	100	93	Na	78	58	45	45	Na			
	9.84	100	100	100	100	90	Na	73	51	39	39	Na			
	11.53	100	100	100	100	85	Na	66	48	42	42	Na			
	12.09	100	100	100	100	76	Na	60	50	43	43	Na			
	14.18	100	100	100	99	31	Na	26	20	17	17	Na			
	16.01	100	100	100	100	99	Na	85	58	45	45	Na			
	17.63	100	100	100	100	98	Na	77	77	76	76	Na			
	21.52	100	100	100	100	93	Na	75	50	39	39	Na			
	23.10	100	100	100	99	89	Na	79	65	58	58	Na			
	23.77	100	100	100	100	99	Na	90	73	56	56	Na			
	27.50	100	100	100	99	88	Na	79	62	51	51	Na			
	27.93	100	100	100	99	93	Na	81	63	47	47	Na			
	29.92	100	100	100	100	100	Na	94	63	42	42	Na			
	32.69	100	100	100	100	77	Na	62	47	38	38	Na			
	35.05	100	100	100	100	99	Na	90	71	49	49	Na			
	37.91	100	100	99	99	86	Na	76	61	49	49	Na			
	42.05	100	100	100	92	36	Na	31	27	24	24	Na			
	43.36	100	100	100	100	89	Na	74	50	41	41	Na			
	44.02	100	100	100	100	43	Na	37	32	30	28	Na			

SITE	DEPTH (m)	STRAT.	LITHOLOGY	pH	EC (dS/m)	SAT%	SATURATION EXTRACT Ca	Mg	Na	SO4	HCO3	Cl	K	SAR
							<——			mg/L			—>	
26	0.0	1	DRIFT	7.5	4.20	53.0	2.00	2.90	53.90	37.40		0.0	.92	34.50
	.50	1	DRIFT	9.6	4.90	89.0	3.50	2.10	57.40	30.50		.30	.82	34.40
	.90	1	DRIFT	7.5	7.46	82.0	22.50	13.20	69.60	99.80		.50	1.29	16.50
	1.80	1	DRIFT	8.2	6.39	127.0	20.20	12.00	60.90	81.10		.30	1.09	15.20
	2.30	1	DRIFT	8.6	7.67	111.0	14.00	5.40	83.50	99.80		1.70	1.17	26.80
	2.70	1	DRIFT	7.5	6.71	68.	21.80	14.90	60.90	93.60		.90	1.03	14.20
	3.79	2	SHALE	8.2	.84	119.5	.13	.13	11.17	8.98	2.40	.28	.32	30.60
	5.50	2	SANDSTONE	8.0	1.65	102.0	.58	.60	18.70	19.96	1.90	.20	.50	24.31
	7.32	2	SILTSTONE	8.4	.97	130.1	.05	.02	14.87	6.99	4.90	.56	.33	78.63
	8.55	2	SHALE	8.4	2.70	80.6	.49	.20	40.26	24.70	10.40	.93	.58	68.63
	13.41	2	SANDSTONE	8.5	.68	198.8	.09	.04	9.35	2.62	6.10	.20	.26	35.80
	14.66	3	SHALE	7.3	1.50	97.8	.13	.07	20.17	9.73	7.20	.65	.50	64.42
	18.03	3	SHALE	7.2	1.20	183.5	.07	.02	16.17	7.74	6.40	.48	.35	74.29
	18.53	3	SHALE	7.4	1.75	155.8	.18	.08	27.04	12.23	7.80	.76	.45	74.63
	18.53	3	SHALE	8.3	.95	330.9	.07	.02	12.78	5.24	5.60	.93	.33	61.45
	20.42	4	SANDSTONE	8.8	.61	120.6	.05	.01	8.39	1.50	6.30	.28	.26	49.16
	22.45	4	SILTSTONE	8.5	.96	235.2	.15	.06	13.65	4.49	67.40	.76	.35	42.35
	23.77	4	SHALE	8.3	1.25	164.0	.30	.07	18.39	5.49	9.90	1.13	.44	42.51
	24.69	4	SANDSTONE	8.8	.58	345.0	.04	.01	8.00	1.50	6.30	.42	.23	51.50
	26.44	5	SHALE	8.4	1.15	205.7	.09	.04	14.22	5.74	6.80	.85	.35	54.46
	27.13	5	SHALE	8.0	2.75	161.9	.69	.17	37.17	29.44	5.40	2.45	.78	56.68
	29.57	5	SHALE											
	30.02	6	SHALE											
		7		8.6	.74	204.1	.13	.04	19.74	3.99	5.30	.65	.32	66.48
	33.84	7	SHALE	8.3	1.40	132.4	.26	.09	19.17	7.99	8.70	1.13	.37	45.45
	34.44	7	SHALE	8.3	1.40	124.5	.27	.08	31.70	9.48	7.70	.93	.49	75.48
	36.88	8	SANDSTONE	8.4	.62	136.2	.10	.04	9.57	1.25	6.30	.48	.64	35.36
	38.27	8	SHALE	8.4	.81	198.1	.13	.03	11.70	2.25	7.80	.45	.36	40.35
	39.96	9	SANDSTONE	8.4	.68	273.5	.08	.03	9.48	1.50	6.90	.54	.31	39.87
	42.72	9	SHALE	8.2	.60	144.7	.34	.09	37.17	26.20	6.50	1.10	1.22	80.09
	43.89	10	SHALE	8.2	1.95	295.6	.20	.07	27.39	15.97	7.20	2.17	.56	73.29
	46.03	10	SHALE	6.3	2.15	111.7	.18	.07	30.61	19.21	6.00	1.47	.51	87.25
	47.38	11	SANDSTONE	8.1	2.05	51.5	.44	.34	29.78	5.24	15.20	1.72	.59	47.73
	48.46	11	SANDSTONE	7.6	5.30	136.7	10.70	2.93	68.30	41.17	2.80	.37	1.23	26.78

SITE	DEPTH	EXCHANGEABLE CATIONS Ca	Mg	Na	K	CEC	CARBONATE Cal	Dol	Total	CLAY MINERALOGY Sm	Ill	Kaol	Chl
26	0.0	5.80	5.50	6.30	.80	18.0	1.6	1.8	3.3	25	50	25	0
	.50	20.60	7.40	20.40	1.10	14.6	3.7	2.2	5.8	45	40	10	5
	.90	25.60	6.20	9.20	.80	17.1	3.1	.8	3.1	35	45	20	0
	1.80	26.30	5.90	11.30	.80	17.0	1.9	.6	2.4	50	35	10	5
	2.30	28.00	5.50	14.70	.80	16.6	2.3	4.5	6.8	50	30	15	5
	2.70	24.60	6.00	7.10	.60	16.4	1.3	3.9	5.2	55	30	10	5
	3.79	18.90	11.32	15.76	2.56		0.0	2.2	1.7	65	25	10	0
	5.50	9.68	5.41	6.50	1.00		1.0	2.4	3.4	95	0	0	5
	7.32	13.53	2.11	25.20	3.44		0.0	3.4	3.2	85	10	0	5
	8.55	24.05	3.51	27.15	2.49		0.0	2.6	1.7	65	25	10	0
	13.41	7.70	1.36	8.70	.95		0.0	4.3	4.0	100	0	3	0
	14.66	23.29	2.75	16.38	1.67		.3	1.4	1.7	75	15	10	0
	18.03	37.03	4.88	34.59	1.08		2.2	2.7	4.9	100	0	0	0
	18.53	20.80	2.81	24.76	2.18		1.8	2.0	3.9	80	15	5	0
	18.53	19.32	3.14	23.63	2.31		2.6	3.8	6.3	80	15	5	0
	20.42	12.48	1.78	15.76	1.05		1.2	1.7	2.9	100	0	0	0
	22.45	25.90	3.26	30.39	2.56		.1	1.5	1.6	85	10	5	0
	23.77	23.78	3.47	28.11	2.77		0.0	1.4	.9	75	20	5	0
	24.69	14.93	2.02	19.61	1.44		.9	2.6	3.5	100	0	0	0
	26.44	17.65	5.29	20.11	2.23		0.0	10.0	9.3	95	0	5	0
	27.13	21.72	4.79	23.33	2.49		0.0	2.8	2.1	70	20	0	10
	29.57	18.38	3.47	16.13	2.18		.4	10.5	10.9	65	15	10	10
	30.02	23.21	2.69	19.49	1.79		0.0	1.2	.9	50	25	15	10
		12.30	1.94	15.00	1.23		0.0	1.3	1.3	100	0	3	0
	33.84	15.98	3.97	13.46	1.97		.3	5.4	5.7	70	20	0	10
	34.44	32.75	3.18	8.26	1.46					65	20	5	10
	36.88	32.25	1.61	10.41	1.05		3.3	10.0	13.4	100	0	3	0
	38.27	23.25	3.93	28.30	2.82		46.6	5.4	52.0	65	25	0	10
	39.96	10.23	2.31	12.35	1.23		1.3	8.3	9.5	100	0	0	0
	42.72	23.50	3.06	37.72	2.79		1.5	2.0	3.5	80	15	5	0
	43.89	32.63	4.17	31.20	1.59		0.0	2.4	2.2	100	0	0	0
	46.03	22.03	3.26	31.20	3.08		0.0	7	.5	95	0	5	0
	47.38	14.95	5.62	13.91	1.79		0.0	15.5	14.7	60	30	10	0
	48.46	12.30	1.94	14.85	1.05		0.0	2.5	2.5	85	10	5	0

		GRAIN SIZE ANALYSES % FINER (units = micrometers)										SULFUR ISOTOPES		
SITE	DEPTH	2000	1000	500	250	100	63	50	20	10	4	2	Sol S	Insol S	Total S
26	0.0	100	99	Na	Na	Na	59	56	Na	Na	12	10			
	.50	100	99	Na	Na	Na	65	61	Na	Na	36	31			
	.90	100	99	Na	Na	Na	64	60	Na	Na	19	15			
	1.80	100	99	Na	Na	Na	62	58	Na	Na	38	34			
	2.30	100	99	Na	Na	Na	63	59	Na	Na	34	30			
	2.70	100	98	Na	Na	Na	61	58	Na	Na	28	26			
	3.79	100	74	61	60	50	Na	42	35	28	27	Na			
	5.50	100	100	100	100	53	Na	38	28	24	24	Na			
	7.32	100	100	100	99	52	Na	39	28	25	25	Na			
	8.55	100	100	100	100	98	Na	86	73	61	61	Na			
	13.41	100	100	100	97	39	Na	31	24	20	20	Na			
	14.66	100	66	49	47	37	Na	25	16	11	11	Na			
	18.03	100	99	98	95	78	Na	62	49	43	43	Na			
	18.53	100	100	100	100	99	Na	83	51	42	42	Na			
	18.53	100	100	100	100	99	Na	99	72	58	46	Na			
	20.42	100	100	100	94	33	Na	28	23	21	21	Na			
	22.45	100	100	100	100	81	Na	72	60	53	53	Na			
	23.77	100	100	100	100	96	Na	88	74	62	62	Na			
	24.69	100	100	100	100	55	Na	43	35	32	32	Na			
	26.44	100	100	100	100	86	Na	70	53	43	43	Na			
	27.13	100	100	100	100	99	Na	90	77	62	62	Na			
	29.57	100	59	38	38	37	Na	32	24	18	18	Na			
	30.02	100	65	48	38	30	Na	17	8	5	5	Na			
		100	100	100	100	39	Na	32	27	23	23	Na			
	33.84	100	100	100	100	99	Na	91	60	41	41	Na			
	34.44	100	37	6	5	4	Na	0	0	0	0	Na			
	36.88	100	100	100	100	95	Na	64	49	36	36	Na			
	38.27	100	99	99	70	26	Na	17	13	12	12	Na			
	39.96	100	100	100	100	64	Na	47	36	32	32	Na			
	42.72	100	100	100	87	25	Na	18	15	13	13	Na			
	43.89	103	100	100	100	97	Na	84	60	51	51	Na			
	46.03	100	98	97	85	33	Na	24	19	18	18	Na			
	47.38	100	98	97	95	77	Na	54	34	25	25	Na			
	48.46	100	100	100	99	49	Na	37	29	28	28	Na			

SITE	DEPTH (m)	STRAT.	LITHOLOGY	pH	EC (dS/m)	SAT%	SATURATION EXTRACT Ca	Mg	Na	SO4	HCO3	Cl	K	SAR
							<—			mg/L			—>	
29	1.00	2	SILTSTONE	8.3	.78	229.1	.22	.12	11.09	6.24	4.50	.73	.32	27.06
	2.44	2	SILTSTONE	8.1	1.10	201.9	.80	.30	17.39	9.98	4.90	1.35	.41	23.48
	3.96	2	SHALE	7.2	2.10	124.2	9.48	2.04	35.17	38.68	12.40	7.39	.26	14.65
	5.27	2	SILTSTONE	8.3	.91	222.1	.65	.26	13.13	8.23	5.80	1.47	1.79	19.51
	6.79	2	SHALE	7.5	2.40	99.8	.78	.33	36.78	20.96	11.40	1.55	.18	49.36
	7.00	2	SANDSTONE	8.3	.88	121.7	.06	.07	10.74	6.24	2.60	.45	3.21	42.77
	9.46	2	SHALE	7.0	2.40	128.0	.42	.18	33.78	24.45	5.50	.54	.59	61.84
	9.89	2	SILTSTONE	6.9	1.05	146.8	.22	.09	14.43	4.24	6.30	.90	.33	36.61
	10.19	3	SILTSTONE	8.7	.57	281.9	.04	.02	6.74	1.87	6.00	.37	.23	40.09
	12.12	3	SANDSTONE	8.3	.78	280.5	.04	.02	10.57	2.25	9.00	.28	.29	58.70
	13.44	4	SHALE	8.4	1.15	207.2	.12	.06	14.43	4.99	8.10	.54	.40	48.41
	16.31	4	SHALE											
		4		8.7	.96	163.4	.13	.06	13.91	2.99	8.20	1.10	.37	44.80
	20.93	4	SHALE	8.6	.69	489.1	.01	.01	8.57	2.43	6.70	.45	.29	79.42
	22.00	5	SILTSTONE	8.8	1.65	188.4	.13	.21	21.39	6.49	11.30	.73	.16	51.51
	22.06	5	SHALE	8.7	1.30	213.5	.10	.07	17.57	6.24	9.50	.54	.83	60.05
	23.46	5	SHALE	8.3	1.90	198.4	.26	.11	25.35	14.47	7.60	1.18	3.21	59.14
	27.43	6	SHALE	6.6	1.35	116.6	.03	.01	5.13	2.99	7.30	.42	.19	37.09
	28.94	7	SHALE	8.6	1.40	139.3	.21	.08	17.22	6.99	7.80	.76	2.56	45.01
	32.61	8	SANDSTONE	8.5	1.10	245.6	.16	.09	13.26	1.87	12.50	.42	.44	37.07
		8		8.6	.74	235.5	.05	.02	8.26	1.87	7.50	.76	.32	41.36
	35.05	8	SHALE	8.2	1.70	186.9	.31	.08	24.09	9.48	10.10	1.64	.67	54.36
	35.91	9	SANDSTONE	8.4	.91	206.3	.04	.02	9.74	4.49	6.50	.54	.35	55.53
	38.37	10	SHALE	8.4	1.35	381.3	1.07	9.55	45.22	16.22	1.60	.45	.49	19.66
	42.06	10	SHALE	8.2	1.90	206.6	4.62	.83	35.65	9.36	8.10	.68	.45	21.59
	47.91	11	SANDSTONE	8.2	1.75	62.8	.11	.06	17.00	8.73	7.40	1.10	2.31	57.83

SITE	DEPTH	EXCHANGEABLE CATIONS Ca	Mg	Na	K	CEC	CARBONATE Cal	Dol	Total	Sm	CLAY MINERALOGY Ill	Kaol	Chl
29	1.00	17.08	7.11	18.98	2.26		.3	1.0	1.3	85	10	5	0
	2.44	14.88	6.49	18.61	2.10		0.0	1.2	1.2	100	0	0	0
	3.96	17.30	6.74	20.17	2.49		0.0	1.1	.7	55	35	5	5
	5.27	15.63	6.07	19.26	2.10		0.0	3.9	2.8	95	5	3	0
	6.79	15.03	3.80	20.76	2.85		0.0	2.3	.8	65	25	10	0
	7.00	5.68	1.74	8.17	.74		0.0	2.7	1.5	100	0	0	0
	9.46	32.00	3.68	35.24	2.15		0.0	6.9	6.8	90	10	3	0
	9.89	21.30	3.02	25.24	2.31		0.0	1.4	.5	80	15	5	0
	10.19	19.58	2.93	24.33	2.46		0.0	1.5	1.2	85	15	3	0
	12.12	18.35	2.89	21.61	2.21		0.0	4.1	3.4	75	20	0	5
	12.12	12.67	2.19	17.15	1.74					100	0	0	0
	13.44	18.23	3.31	21.57	2.36		0.0	7.5	6.1	85	5	0	10
	16.31	8.43	1.03	5.17	1.03		1.2	1.5	2.7	30	55	15	0
		7.20	1.45	8.78	1.15		1.5	1.6	3.1	100	0	3	0
	20.93	19.83	4.42	24.61	2.18		1.1	2.3	3.3	90	10	3	0
	22.00	11.70	3.14	13.37	1.08		0.0	7.6	6.7	100	0	0	0
	22.06	35.50	3.26	45.07	3.76		0.0	7.3	6.9	85	10	0	5
	23.46	21.88	3.84	25.04	2.21		.8	3.9	4.7	70	20	0	10
	27.43	19.20	2.81	18.83	2.00		0.0	1.9	1.5	45	35	5	15
	28.94	16.35	3.26	17.63	2.03		0.0	4.1	3.4	75	15	5	5
	32.61	11.53	2.19	13.78	1.03		0.0	3.4	3.0	100	0	0	0
		17.85	3.72	20.15	1.67		0.0	4.3	4.2	100	0	3	0
	35.05	26.58	3.55	30.48	2.33		.2	1.9	2.1	95	0	5	0
	35.91	17.25	3.06	20.33	1.87		.6	44.2	44.9	95	5	3	0
	38.36	33.43	4.67	40.87	2.05		0.0	2.9	2.9	100	0	0	0
	42.06	27.53	3.76	30.74	2.00		0.0	2.6	1.7	75	20	5	0
	47.91	16.05	3.02	20.57	1.90		.2	2.0	2.2	85	10	0	5

SITE	DEPTH	GRAIN SIZE ANALYSES % FINER (units = micrometers) 2000	1000	500	250	100	63	50	20	10	4	2	SULFUR ISOTOPES Sol S	Insol S	Total S
29	1.00	100	100	100	93	33	Na	24	19	18	18	Na			
	2.44	100	100	100	100	89	Na	54	43	38	38	Na			
	3.96	100	100	100	100	86	Na	63	42	35	35	Na			
	5.27	100	100	100	100	94	Na	71	56	42	42	Na			
	6.79	100	100	100	100	66	Na	42	30	26	26	Na			
	7.00	100	100	100	99	68	Na	55	40	29	29	Na			
	9.46	100	99	99	96	70	Na	53	35	26	26	Na			
	9.89	100	100	100	100	83	Na	67	49	40	41	Na			
	10.19	100	100	100	100	50	Na	40	31	27	27	Na			
	12.12	100	100	100	100	98	Na	89	52	39	39	Na			
	12.12	100	100	100	100	84	Na	77	72	65	64	Na			
	13.44	100	100	100	100	100	Na	95	72	46	46	Na			
	16.31	100	38	7	5	3	Na	0	0	0	0	Na			
		100	100	100	75	26	Na	22	18	16	16	Na			
	20.93	100	100	100	100	96	Na	83	62	47	47	Na			
	22.00	100	100	100	100	53	Na	41	29	27	27	Na			
	22.06	100	100	100	100	96	Na	90	70	51	51	Na			
	23.46	100	100	100	100	97	Na	88	71	58	58	Na			
	27.43	100	73	60	53	41	Na	26	18	12	12	Na			
	28.94	100	100	100	100	99	Na	84	48	36	36	Na			
	32.61	100	100	100	93	34	Na	26	21	21	21	Na			
		100	100	100	100	83	Na	63	40	34	34	Na			
	35.05	100	100	100	100	96	Na	82	72	56	56	Na			
	35.91	100	100	100	100	87	Na	59	40	35	35	Na			
	38.36	100	100	100	100	92	Na	82	70	62	62	Na			
	42.06	100	100	100	100	99	Na	86	73	62	62	Na			
	47.91	100	100	100	100	80	Na	65	46	35	35	Na			